COULD BATMAN EXIST?

THE REAL-LIFE PHYSICS BEHIND FLIGHT, SPEED AND SUPER STRENGTH

HOW IT WORKS

SCIENCE ENT TECHNOLOGY TRANSPORT HISTORY SPACE

INSIDE

NATURAL BORN KILLERS

The tactics of the world's greatest hunters

TOMORROW'S CITIES

How robotics and virtual reality will revolutionise retail

FIND OUT

- WHAT IF THE MOON DISAPPEARED?
- ARE ELEPHANTS AFRAID OF MICE?
- WHY DO WE HAVE FRECKLES?

THE EYE

Take a closer look at how we focus on near & distant objects

SPACE WEATHER

How extreme cosmic forecasts affect our planet

BLACK HAWK HELICOPTER

Uncovering the history behind the mechanical marvel

897 FACTS AND ANSWERS INSIDE

FLYING AT 80,000 FEET

SPIES IN THE SKY

REVEALED: TOP-SECRET MILITARY TECH THAT'S WATCHING YOU RIGHT NOW

12 SURPRISING FACTS ABOUT **THE SOLAR SYSTEM**

+ LEARN ABOUT

- INSIDE AN IRON
- WIND PATTERNS
- MOUNTAIN BIKES
- VICTORIAN MAIDS
- TESLA COIL
- FISH SCALES
- STALACTITES
- ANIMAL HEARTS
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ISSUE 83

WELCOME

The magazine that feeds minds!

"The red fox can hear prey under a metre of snow"

Natural Born Killers, page 54

Meet the team...

Jo
Features Editor
I've only just recovered from Christmas shopping and the sales, so I'm very much looking forward to the tech that will make it easier in the future.

Jackie
Research Editor
I was somewhat disappointed to learn that flying through the asteroid belt would be nowhere near as exciting as *Star Wars* would have us believe.

Katy
Production Editor
Animals often work together when hunger strikes – whether it's a pod, pride or pack, these ruthless predators are the ultimate team players!

Duncan
Senior Art Editor
Can I run as fast as The Flash? Or am I as strong as Superman? In my head I am, but in reality, could anyone come close to their superpowers?

Briony
Assistant Designer
Think you're clued up on Henry VIII? Head over to page 79 for some shocking revelations about one of England's most controversial kings.

FOLLOW US... How It Works magazine @HowItWorksmag

Shrouded in mystery, flying at the very edge of space, spy planes are the pinnacle of aviation technology.

The recent Cold War-set Tom Hanks movie *Bridge of Spies* shows the fall-out caused when a high-flying spy mission goes wrong, but tomorrow's eyes in the sky will go further than ever before to ensure they stay out sight and out of reach.

Another movie on the horizon is *Batman V Superman: Dawn Of Justice*. Before I became Editor of **How It Works**, I worked on the best sci-fi and fantasy magazine on the shelves, **SciFiNow**. Writing about comic book movies was a weekly occurrence and so I had to find a way to squeeze some spandex and superpowers into this science and technology magazine.

We have equations to explain why Gwen Stacy didn't make it, the lowdown on the real-life Iron Man suits and the physics of falling from a building. Hint: it doesn't work out well for our Caped Crusader...

Enjoy this blockbuster issue!

Jodie

Jodie Tyley
Editor

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Meet the experts...

Laura Mears
Ahead of the cinematic release of *Batman v Superman*, Laura explains the real-life science behind the superheroes. Discover whether Batman really could survive a fall and more, over on page 22.

Gemma Lavender
This month, astrophysicist and **All About Space** Editor Gemma counts down the three biggest objects in the universe and tells us all about the Pacman Nebula.

Tim Williamson
The Editor of **History Of War** takes us for a spin in a Black Hawk helicopter, explaining its key role in the Battle of Mogadishu and the covert operation to kill Osama Bin Laden.

Kat Arney
Geneticist Dr Kat Arney explains the mystery of junk DNA, the 'dark matter' that can be found in your genome. Find out more about it in her book, *Herding Hemingway's Cats.*

Alicea Francis
A day in the life of a Victorian maid was exhausting, as **All About History** magazine's Alicea reveals. She also takes a look at the life of the infamous King Henry VIII.

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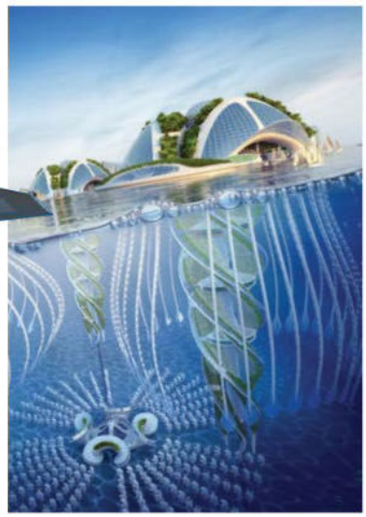
REGULARS



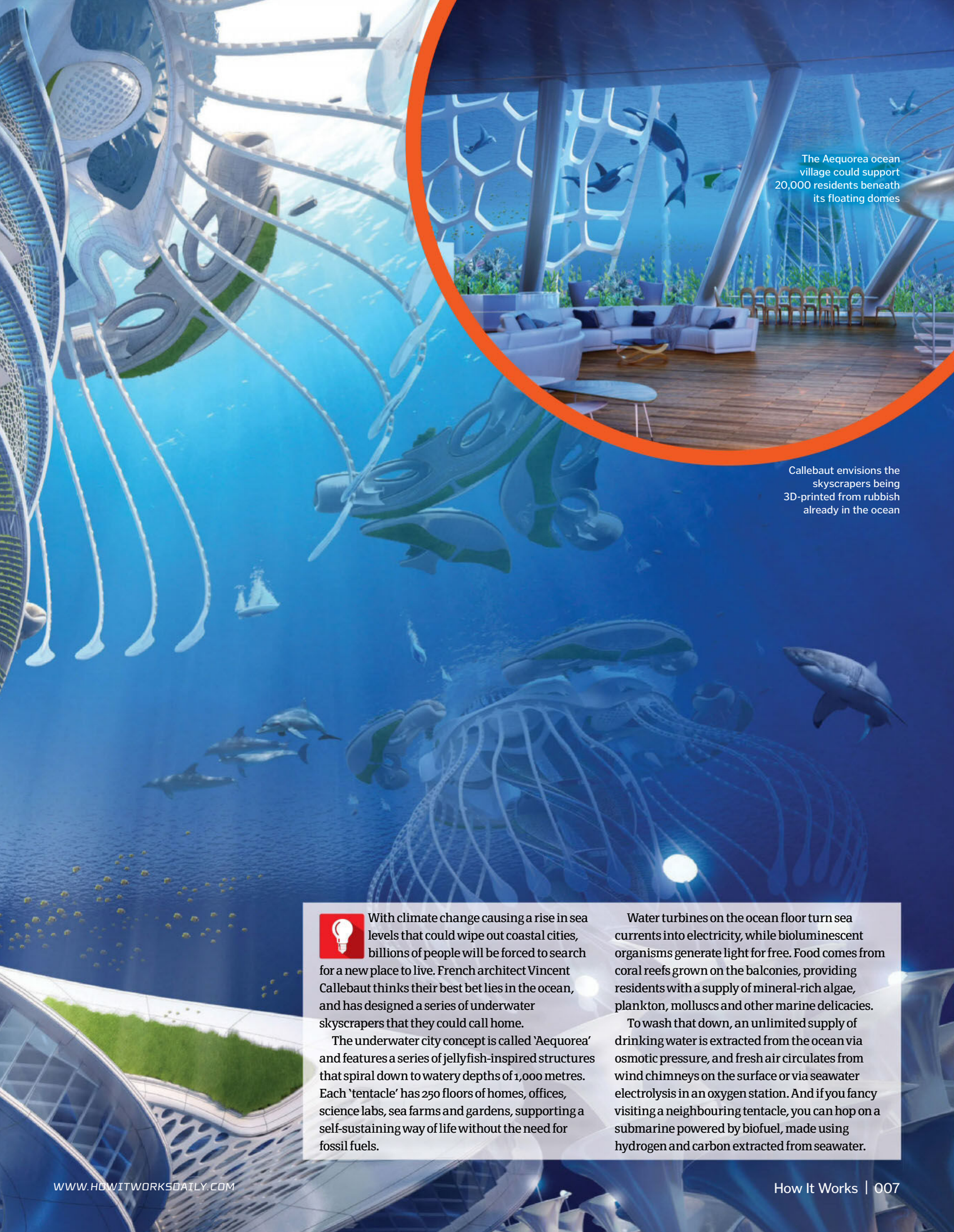
GLOBAL EYE

Showcasing the incredible world we live in

Cities under the sea

Could underwater skyscrapers be the future of eco-friendly living?

Fruit and vegetables could be grown in structures above the surface



The Aequorea ocean village could support 20,000 residents beneath its floating domes

Callebaut envisions the skyscrapers being 3D-printed from rubbish already in the ocean

With climate change causing a rise in sea levels that could wipe out coastal cities, billions of people will be forced to search for a new place to live. French architect Vincent Callebaut thinks their best bet lies in the ocean, and has designed a series of underwater skyscrapers that they could call home.

The underwater city concept is called 'Aequorea' and features a series of jellyfish-inspired structures that spiral down to watery depths of 1,000 metres. Each 'tentacle' has 250 floors of homes, offices, science labs, sea farms and gardens, supporting a self-sustaining way of life without the need for fossil fuels.

Water turbines on the ocean floor turn sea currents into electricity, while bioluminescent organisms generate light for free. Food comes from coral reefs grown on the balconies, providing residents with a supply of mineral-rich algae, plankton, molluscs and other marine delicacies.

To wash that down, an unlimited supply of drinking water is extracted from the ocean via osmotic pressure, and fresh air circulates from wind chimneys on the surface or via seawater electrolysis in an oxygen station. And if you fancy visiting a neighbouring tentacle, you can hop on a submarine powered by biofuel, made using hydrogen and carbon extracted from seawater.

An air tunnel running through the car will reduce drag and help to cool the batteries

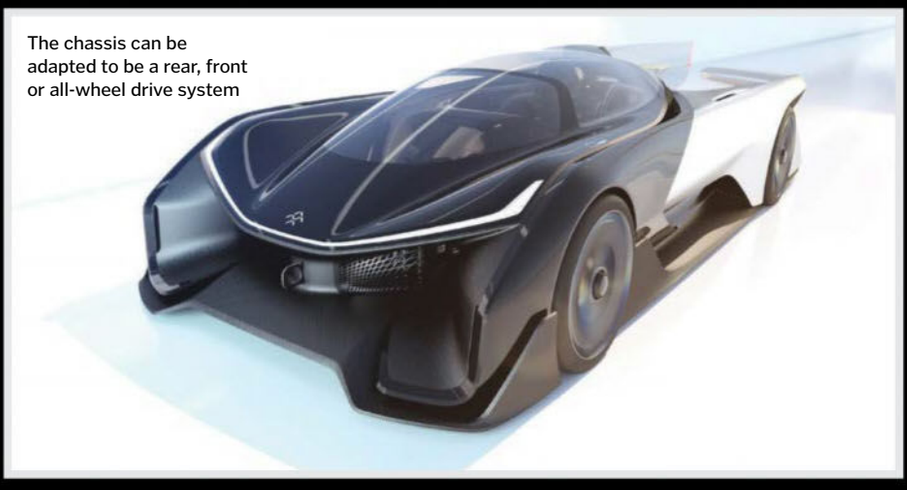
A real-life Batmobile

This electric supercar is billed as "a tablet on wheels"

Tesla rival Faraday Future has unveiled an extreme concept car that is fully autonomous. Owners can use their smartphone to set up the vehicle before plugging it into the steering wheel, and the car promises to learn from their preferences.

The electric FFZERO1 features an innovative 'variable platform architecture', which means the powertrain can be adapted for different battery packs and motors to alter power output and drive. In theory, this will speed up the production of various models, racing ahead of the rest of the auto industry.

In the future, the company envisions a subscription-based model, where you can order different versions of the self-driving car to your door, be it a practical people carrier or a more sporty number that can go from 0-60 in under three seconds. It's purely a concept right now, but Faraday Future plans to produce its first electric car by 2018.



The chassis can be adapted to be a rear, front or all-wheel drive system

Studying Martian sand dunes

NASA's Curiosity explores the Red Planet's windswept terrain

While conducting the first ever close-up study of extraterrestrial sand dunes, Curiosity snapped a stunning panorama of the Namib Dune near Mount Sharp. The dune's steep slope has formed as a result of the dune sheltering its windward side from sand being blown across the planet's surface. This has caused the sand to fall out of the air and build up a steep slope, before flowing in mini-avalanches down the face. NASA hopes the study will reveal new information about how wind moves grains of sand with little gravity and without much of an atmosphere.

A 360-degree view of the Namib Dune's downwind face with Mount Sharp in the background

Playing Brain Games

The award-winning series is back to unlock the secrets of your mind

Can you trust your own brain? Hit TV show *Brain Games* reveals the truth, using a series of mind-blowing hidden camera social experiments to reveal how we each perceive the world in different ways. "There is no real empirical reality that you get to experience," says host Jason Silva. "You see things only through your built-in misconceptions, preconceptions and cultural biases. That's what *Brain Games* is really about; we're showing you some science and entertaining you, but what we really want you to understand is what you see isn't always what you get."

Brain Games premieres on **Sundays at 7pm** on the **National Geographic Channel**

Brain Games host Jason Silva (left) has travelled the world to learn more about the human brain

GLOBAL EYE

10 COOL THINGS WE LEARNED THIS MONTH

Star clusters could host alien life

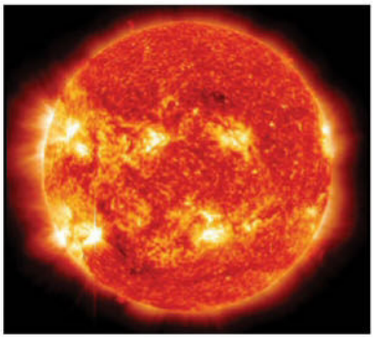
The age and density of globular star clusters makes them likely candidates for supporting extraterrestrial life, a new study suggests. These massive groupings of stars formed nearly 10 billion years ago, creating the ideal conditions for life to thrive, with plenty of time for it to evolve into intelligent beings. The close proximity of stars would also make interstellar travel easy, giving any beings the opportunity to explore and communicate.

Plants use mini stink bombs as self-defence

If you disturb the roots of a plant belonging to the Mimosa genus, make sure you're holding your nose. Tiny, hair-like sacs dotted along the roots of some species release a cocktail of foul-smelling sulphur compounds when touched. This is believed by experts to be a defence mechanism designed to deter predators or to stop other plants' roots from growing in their territory.

Roman sanitation helped spread parasites

Rather than improving hygiene with the invention of public toilets, sewer systems and heated public baths, the Romans made it worse. New archaeological research has found that parasites increased during this period, perhaps as a result of communal bathing and infrequent water changes.



You would weigh 20 times more on the Sun

A new method for more accurately measuring the gravitational pull of distant stars has been found, revealing just how much you would weigh on the Sun. The new technique also helps reveal how big and bright a star is, which could assist scientists in finding habitable planets beyond our Solar System.

There's a games console for dogs

If you're worried about your canine pal getting bored while you're not home, then the CleverPet Hub will keep them entertained and well-fed. The unit presents your pooch with a series of light and sound-based games that they can play using the touchpad. If they solve the puzzle, they're rewarded with a treat, and you can track their progress via an app.

Black holes can burp

A supermassive black hole 26 million light years away has been spotted 'burping' hot gas after feeding on the stars, dust and gas in its surroundings. "Our observation is important because this would likely happen very often in the early universe, altering the evolution of galaxies," says Eric Schlegel of the University of Texas in San Antonio, who led the study. "It is common for big black holes to expel gas outward, but rare to have such a close, resolved view of these events."

You could charge your phone by walking

Researchers at MIT have developed a method for harvesting energy from natural motions such as walking. The device features a layer of polymer sandwiched between a metal that is flexible enough to be used in wearable tech. When bent, the pressure difference between the layers squeezes lithium ions through polymer soaked with liquid electrolyte, producing a voltage and electrical current.

Tiny chameleons have powerful tongues

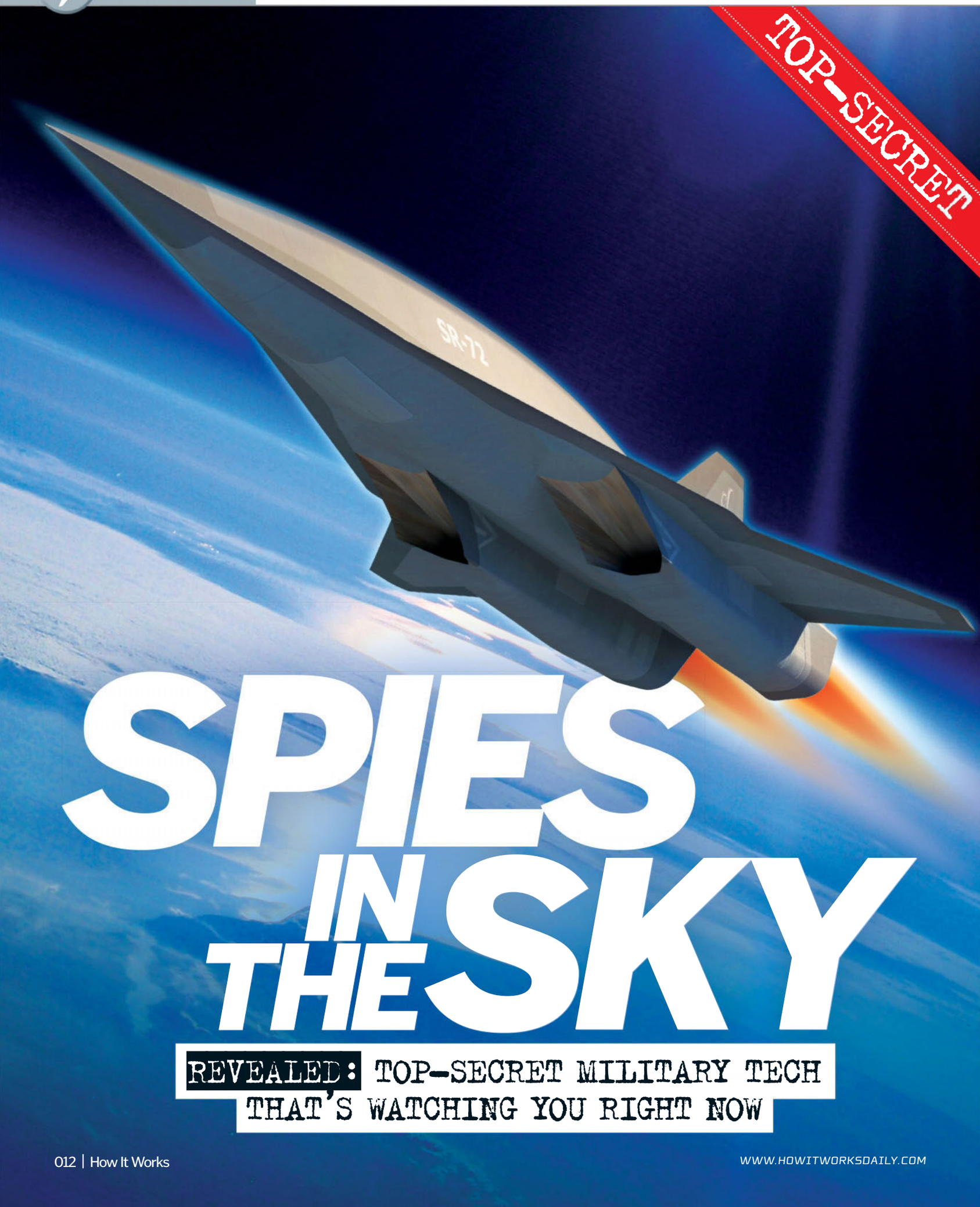
Chameleons catch their prey with their tongues, and it's the smaller critters that pack the biggest punch. That's according to a study by Brown University, which documented the speeds of 20 species. One thumb-sized creature was able to fire out its tongue from 0 to 97 kilometres per hour in a hundredth of a second! This special skill helps the smaller animals compete for food.

The periodic table has four new elements

Filling in the gaps are the as-yet-untitled elements 113, 115, 117 and 118, the first new additions since 2011. These new super-heavy elements were made by smashing atoms together in a particle accelerator, but only last for a fraction of a second before decaying into other isotopes.

The patterns of cats' fur is random

New findings about how black and white cats develop their patches have revealed surprising results. It was previously thought that pigment cells move too slowly while the embryo is forming, leaving certain areas white. However, the new study shows that the cells are not sent in a particular direction during early development, instead moving and multiplying randomly to create patterns.



SPIES IN THE SKY

REVEALED: TOP-SECRET MILITARY TECH THAT'S WATCHING YOU RIGHT NOW

On 1 May 1954, the Soviet Union's newest bomber – the Myasishchev M-4, nicknamed 'Hammer' – soared above Red Square in Moscow. It wasn't long after the successful detonation of a hydrogen bomb, and the US watched as its former World War II ally turned into a Cold War enemy.

Gaining intelligence was almost impossible, as surveillance planes that tried to enter Soviet airspace were shot down. The Lockheed U-2 would prove to be a complete game-changer. Developed at what went on to become the top secret Area 51 facility, this plane could fly out of reach of enemy fighters and missiles, taking detailed aerial photographs of airfields, factories and shipyards. Knowledge is power, and these images proved to the US that there was no immediate threat and so a deadly arms race – and potential nuclear war – was averted.

Over the course of their history, spy planes have become the most feared aircraft, despite carrying no weapons. Deployed by government and military forces, these eyes in the sky can be used for many different tasks, from patrolling borders and gathering information behind enemy lines, to monitoring battlefields for strategic decision-making.

Getting the information they need quickly and discreetly is the key aim for engineers. Modern spy planes use cutting-edge science and technology to do this, but historical planes were able to achieve amazing feats too. One such example is the SR-71 Blackbird. It was built in the analogue age, taking off in 1964 and performing reconnaissance missions until its retirement in 1990.

Despite being 32 metres long with a 17-metre wingspan, this black behemoth could fly faster than a rifle bullet, hitting Mach 3 – three times the speed of sound, over 3,700 kilometres per hour. Its distinctive curved shape with a sharp edge that ran along the body of the plane presented very few surfaces for radar detection, and using

Many technologies invented for the SR-71 are still in use today

Inside the SR-72

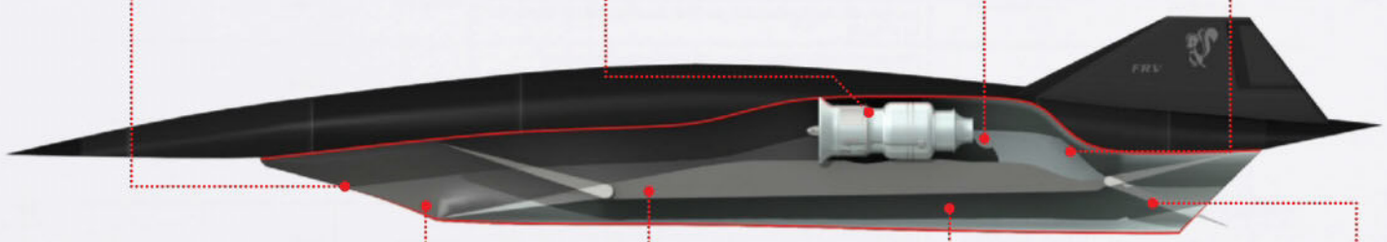
Blackbird's successor has a combined cycle [redacted] propulsion system for reaching [redacted] hypersonic speeds

Scramjet force
The dual-mode ramjet engine switches to scramjet (supersonic ramjet) mode to accelerate from Mach 5 to Mach 6. It uses supersonic air for combustion to reach speeds of around 7,400km/h.

Combined cycle
A turbojet engine is combined with a supersonic combustion ramjet engine for optimum performance.

Turbojet
The turbojet engine provides the initial thrust to accelerate the SR-72 from takeoff to Mach 3.

Ramjet force
The ramjet engine then takes over, accelerating the aircraft from Mach 3 up to Mach 5.



Common nozzle
The turbojet and ramjet/scramjet engines share an air inlet nozzle to reduce drag.

Air inlet
Air is scooped into the inlet and compressed as it enters the diffuser.

Combustion
Air and fuel are fed into a combustion chamber and ignited.

Thrust
An exhaust nozzle accelerates the burst of expanding hot air, producing a huge amount of thrust.

"Throughout history, spy planes [redacted] have become the [redacted] most feared aircraft, despite carrying no [redacted] weapons"

The SR-72 will reach speeds of Mach 6, double that of its predecessor

top-of-the-range photographic equipment for the time, Blackbird captured images of the ground from an altitude three times the height of Everest. Although some were lost in accidents, none were ever shot down or captured by an enemy.

Now that this godfather of spy planes is out to pasture, Lockheed Martin's Skunk Works division is developing a faster, unmanned successor, the SR-72 (nicknamed the 'Son of the Blackbird'). The engines will use a hybrid system to reach hypersonic speeds, enabling the aircraft to cross an entire continent in an hour. The air friction of this speed alone could melt steel, so the SR-72 is likely to be made of composite materials, similar to those used for space shuttles and missiles. It will need to be capable of withstanding temperatures in excess of 1,000 degrees Celsius and be sealed to stop lethal air leaks.

The technology needed to take photographs at this kind of speed will also be an incredible feat, and the exact makeup of this aircraft's gadgetry has not been confirmed, or perhaps even invented yet. What we do know is that it won't just be an observer. This new unmanned plane will be armed to the teeth, launching bombs to hit targets from altitudes of around 24 kilometres – up in the stratosphere.

Aerodynamics play a huge part in spy plane tech – aircraft like the SR-72 need to be designed to cope with stresses experienced when travelling at such high speeds. The Son of the Blackbird will need to be incredibly well balanced to deal with the changes between subsonic, supersonic and hypersonic flight to ensure that the craft is not ripped apart by the shifting centre of lift.

However, the Global Hawk, for example (an Unmanned Aerial Vehicle made by Northrup Grumman) is nothing like how you might

The SR-71 carried two crew members, but its successor is likely to be unmanned

Boeing [redacted] Poseidon P-8

This sky-borne sub hunter [redacted] scans the waters [redacted] for unwanted aquatic visitors

Based upon the tried-and-tested body of the Boeing 737-800 commercial airliner and the wings of Boeing's 737-900, the Poseidon P-8 is an advanced maritime patrol and reconnaissance aircraft. Featuring all kinds of task-specific technology, the P-8 is able to fly fast and low, cruising above the sea to seek out submarines that can pose threats to aircraft carriers.

Six extra body fuel tanks extend the plane's range to find the subs. Some variants of the Poseidon P-8 model use radar, a magnetic anomaly detector and electronic intelligence sensors to monitor telecommunications and infrared imaging to keep tabs on shipping. It can also deploy expendable sonobuoys to act as satellite sensors in the field.

But that's not all this spy plane can do. With its strengthened fuselage, the Poseidon also boasts missiles, mines and torpedoes in its arsenal, making it ready to aim, fire and dispatch a rebel submarine if ever required.

TOP-SECRET

Sonobuoys listen for sounds in the water and relay information to the aircraft

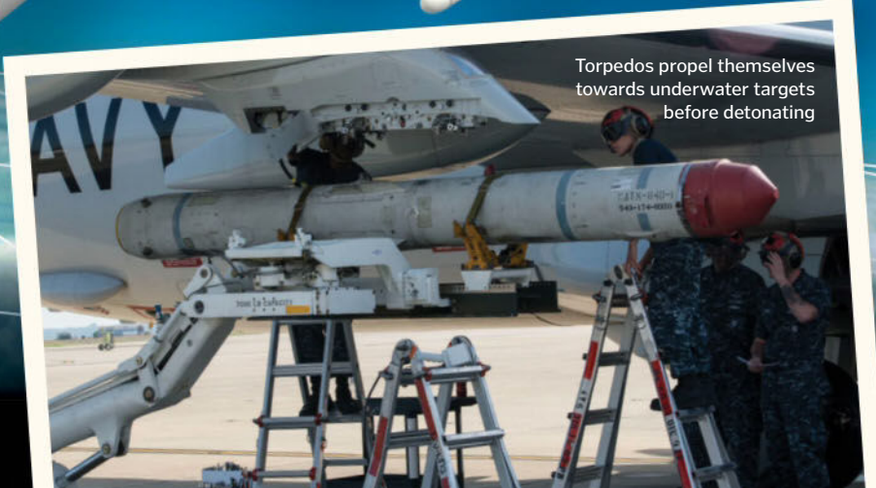
Satellite antennae
Perched atop the tailfin sits an array of military communications antennae.

Magnetic anomaly detector (MAD)
On some models, this submarine-detection apparatus is mounted on an extension at the back of the aircraft to minimise interference.

Sonobuoy launch tubes
Over 100 sonobuoys can be launched per flight, to detect submarine activity and send acoustic data to the plane.

Arsenal
A variety of weapons can be fitted, including torpedoes, depth charges and anti-ship missiles.

"With [redacted] its strengthened fuselage, [redacted] the Poseidon also boasts [redacted] missiles, mines and torpedoes [redacted] in its arsenal"



Torpedos propel themselves towards underwater targets before detonating

For every advance in spy plane detection, there's an advance in submarine evasion

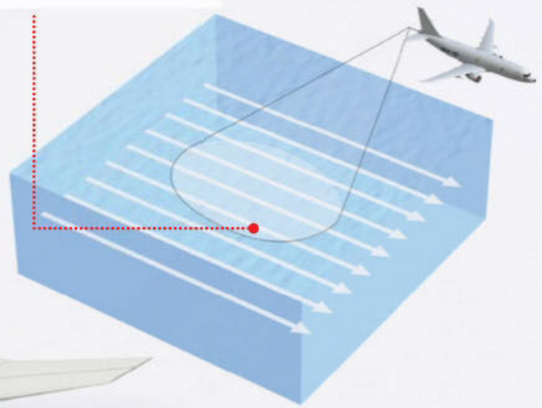
Stealth subs

You could easily think that, for a giant metal tube in a featureless ocean, there's nowhere to hide. But once again, tech is lending a hand. Where some aircraft use magnetic anomaly detectors to seek out magnetic signatures, submarines will employ 'degaussing' techniques to evade detection. This involves using electromagnets to create another magnetic field that matches the background field, rendering the signature undetectable.

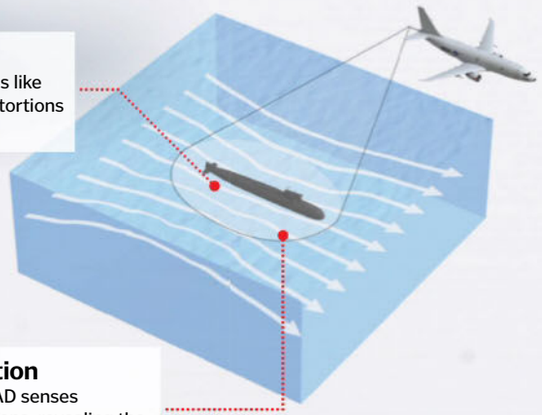
Another stealth method is to deflect sonar. Coating materials modify the sound waves hitting a submarine so that they don't bounce back. Such materials in development include a substance that 'wicks' sound waves off a sub like water off a duck's back, as well as a material that looks like miniature bubble wrap, which soaks up and disperses sound.

As sound is a big part of sub detection, one of the key ways to avoid being found is to reduce the din. All of the machinery in a submarine will be placed upon acoustic and vibration deadening buffers to minimise the overall noise of the vessel.

Detection
The MAD uses a magnetometer to sense Earth's magnetic field.



Distortion
Large metal structures like submarines cause distortions in the magnetic field.



Location
The MAD senses distortions, revealing the submarine's location.

Surveillance strategies

The methods that spy planes [redacted] use from above [redacted] to find and track mobile communication signals

1. Power up the dirtbox

Planes are often equipped with tech known as dirtboxes, so-called for the initials DRT that stand for Digital Receiver Technology. They work by mimicking the job of telecommunication towers, tricking mobile phones into sending unique registration data to the dirtbox device.

2. Scan and single out

The dirtbox can scan thousands of phones before it reaches its intended target. Once the suspect has been located and locked on to, the DRT disregards the other phones, and focuses on collecting information.

imagine a top-level spy plane to look. It has a bulging front profile and a somewhat chunky tail end, but this amazing surveillance drone is able to fly across the world to deliver real-time ISR (Intelligence, Surveillance and Reconnaissance) data to its controllers at US Air Force ground bases.

Unmanned aircraft offer numerous advantages for the advance of spy planes. First of all, engineers do not need to construct a cockpit that safeguards human life. When it comes to creating a monster machine that operates on the very edges of space, this is a money, time and space-saving bonus. The other benefit of using a spy drone instead is that it can keep going for longer than a mission with an onboard pilot. Many drones can also be pre-programmed to carry out assignments even if contact is lost with its base team.

One such spy drone causing ripples in aerial reconnaissance is Northrop Grumman's RQ-180. Not much is known about this robot apart from the fact that it exists, and that the stealth drone is designated for flying in defended airspace for spying on heavily armed rival nations. It's thought that to evade radar detection, this drone may be designed with the 'cranked kite' formation, where the shape is a fusion of the 'kite' and 'flying' wing formations. The chunky and angular shapes are designed to scatter oncoming radar waves, so that they can't be bounced back to their location and the plane can fly undetected.

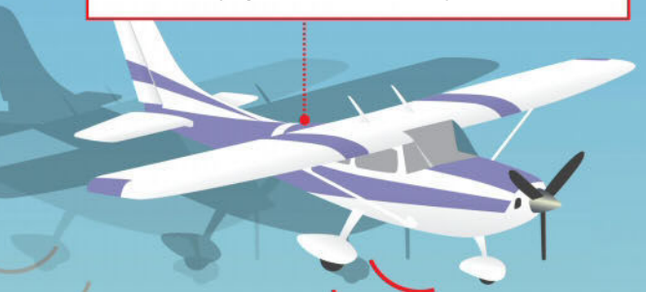
TOP-SECRET

The Global Hawk surveillance drone has been used in combat in Iraq and Afghanistan

"The dirtbox can scan thousands [redacted] of phones before [redacted] it reaches [redacted] its intended target"

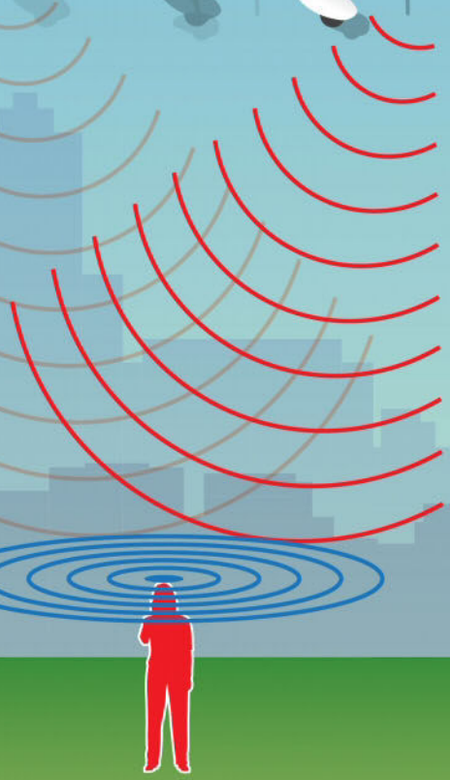
3. Get into location

The plane manoeuvres into the best position to get a clear signal from the mobile phone in question. It can detect signal strength and geographical location of the user as well as obtain identifying information about the phone's owner.



4. Homing in

Using this information from the mobile phone signal, a suspect's location can then be pinpointed to within three metres. The dirtbox can even help to track a person down to a specific room in a building.



The unlikely spy plane

Cessna is a company known for making light aircraft, the type that any pleasure pilot would take out for an afternoon's flight. Yet in 2015 the internet saw an explosion of reports that the FBI had outfitted some of these nondescript civilian airplanes with high-tech surveillance gadgetry.

The Cessna 182 'Skylane' is one such craft, having had the investigative force of the Bureau behind its major upgrades; the thermal imaging and infrared cameras, night vision technology plus mobile phone interceptors are just a few add-ons. These features help the FBI to follow on-going investigations targeting specific individuals, as well as support law enforcement.

These humble planes have also received high-grade makeovers from the US Air Force, who have kitted out a 182 Skylane with modifications to be used in military training exercises. The plane has all the intelligence, surveillance and reconnaissance sensors it needs to be able to mimic that of a Predator Unmanned Aerial Vehicle.

The single-engine Cessna 182 Skylane plane is proving an excellent choice for unobtrusive surveillance

© WIKI

As well as the shape of the aircraft, radar-absorbent materials can also be used to make them less visible. When the waves from the seeking radar hit it, these coatings can deflect the waves and send them in another direction, or in such a manner that the deflected waves cancel out the incoming ones. This renders the craft practically undiscoverable.

Stealth, speed and strength are all very well, but if a spy plane can't carry a decent payload then it's not worth its salt. There are countless

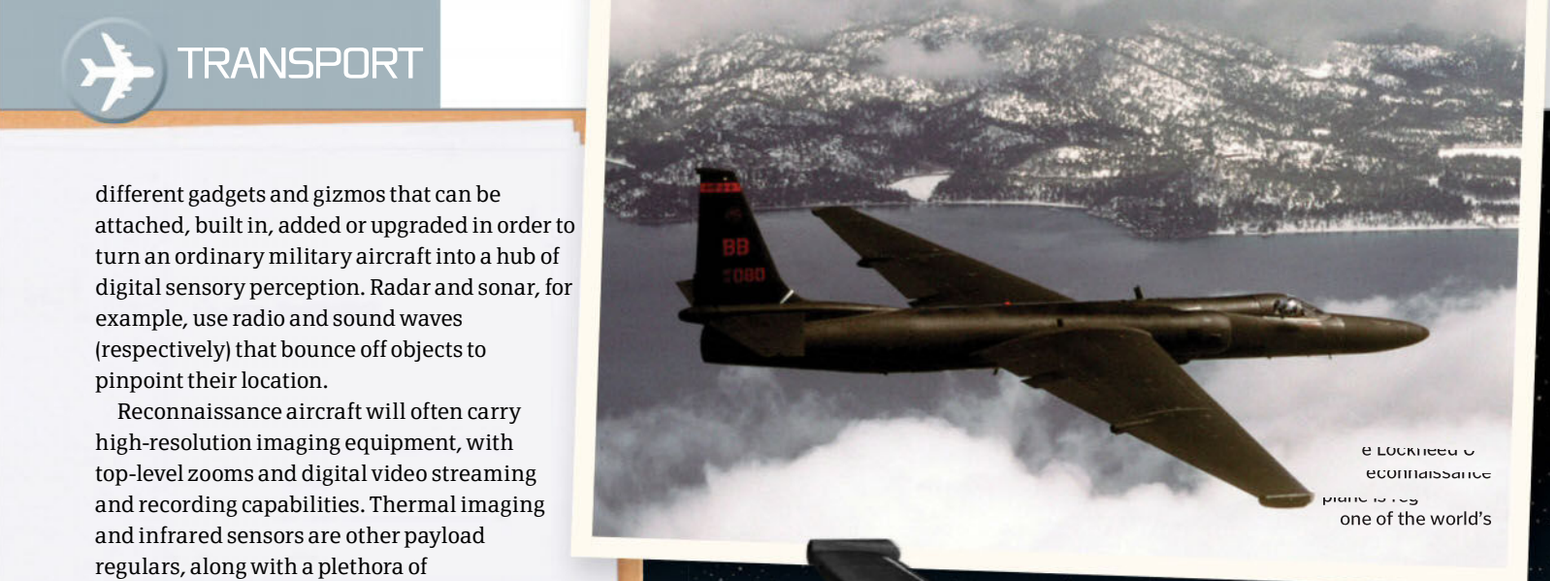
Spy planes are capable of reaching enormous altitudes

different gadgets and gizmos that can be attached, built in, added or upgraded in order to turn an ordinary military aircraft into a hub of digital sensory perception. Radar and sonar, for example, use radio and sound waves (respectively) that bounce off objects to pinpoint their location.

Reconnaissance aircraft will often carry high-resolution imaging equipment, with top-level zooms and digital video streaming and recording capabilities. Thermal imaging and infrared sensors are other payload regulars, along with a plethora of communications interceptors, acoustic monitoring and many other ways to listen in on the rest of the world. The data is delivered to analysts either onboard or on the ground via high-speed real-time links, so the intelligence gathered can be used advantageously.

It would seem that the future for ISR missions involves plenty of speed, power and altitude with the benefit of automated features. Although there are no plans to retire the old faithfuls like Lockheed's U-2 Dragon Lady just yet, there are also plenty of rumours circulating about plans for faster, meaner, more multifunctional spy planes.

One such concept is the TR-X – another Lockheed invention from their famous Skunk Works spy plane creation station in California. The planning stages are still in their infancy, but Lockheed have stated this spy plane will take the best bits of all the other great spy planes in the skies today and roll them into one mega plane that could be deployed by 2030. You could keep your eyes on the sky, but you would probably never see it coming.



e Lockheed U
econnaissance
plane is reg
one of the world's

The Lockheed U-2 cockpit is packed full of high-tech features designed to inform and assist the pilot

TOP-SECRET

Lockheed U-2

The plane that peeked around the Iron Curtain is still going strong

Named 'Dragon Lady' by the US Air Force, the U-2 was the brainchild of engineer Clarence 'Kelly' Johnson and went from design to test flight in just nine months. The slender body and long wingspan allow it to fly a range of over 4,800 kilometres at an altitude of over 21 kilometres.

The next-gen U-2 family, the U-2S, was built in the 1980s and is expected to be operational beyond 2050. These planes are fitted with state-of-the-art sensor systems that are able to collect data day and night, in all weather. The intelligence is distributed in real time for analysis and exploitation over super-fast digital links.

Today, some of the U-2's work is for NASA, equipped with various sensors to conduct atmospheric tests. U-2s have also patrolled the skies above Iraq and Afghanistan, intercepting insurgent communications and using their incredible imaging sensors to detect small disturbances on the ground, alerting troops to the presence of improvised explosive devices and mines.

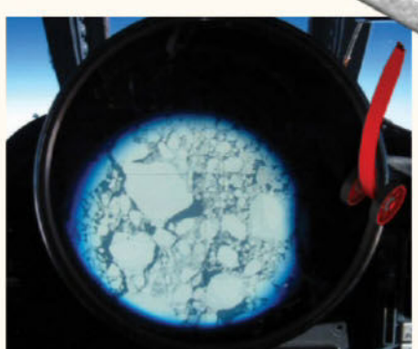
U-2 pilots wear pressurised space suits to keep themselves protected when flying at high altitude

Sensors and display
Electro-optical/infrared sensors feed data into the cockpit, presenting information clearly to the pilot.

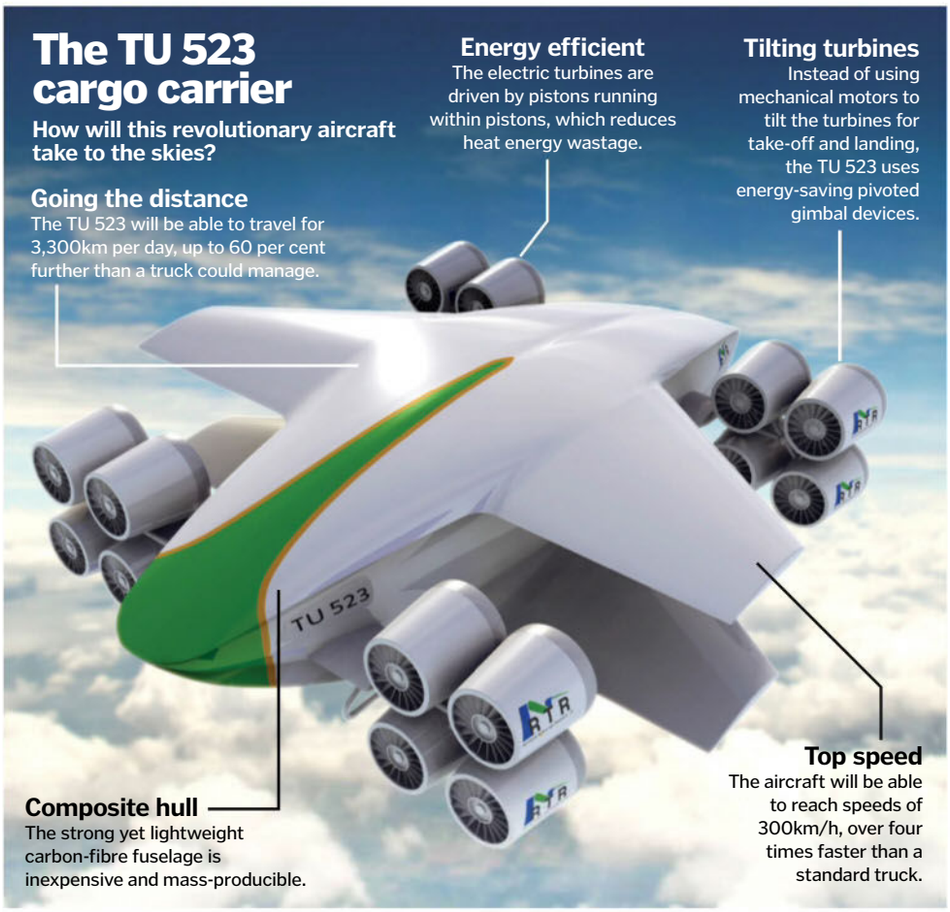
Altitude climb
The U-2 is able to climb to 15,240m in about 20 minutes, and 19,812m within an hour of take-off.

"The next-gen U-2 family, the U-2S, was built in the 1980s and is expected to be operational beyond 2050"

Safety car
Landing a U-2 is very tricky and requires the help of another pilot giving radio instruction from a safety car.



NASA captures atmospheric data using the U-2



The future of VTOL aircraft

Meet the fleet that could revolutionise heavy cargo transportation

The huge cargo containers that travel the world on enormous ships are currently passed onto large trucks when they reach port, and driven to their final destination by road. However, British company Reinhardt Technology Research (RTR) believes it would be quicker, cheaper, and more environmentally friendly to fly them instead.

The company has recently designed the TU 523, a vertical take-off and landing (VTOL) aircraft that is capable of transporting heavy shipping containers without the need for expensive new infrastructure. The craft uses a hybrid electric generator to supply power to a series of electric turbines on demand, which can tilt horizontally and enable vertical take-off and landing.

Once in the air, the turbines tilt back again, while the wings generate lift just like on an airplane. RTR has already built a 1:4 scaled model of the TU 523, which it is preparing to send on a 60-day journey from the UK to South Africa in 2016. It will then develop a full-scale version over the next three years, which can be mass-produced at a capacity of 30 units per month and cost no more than £400,000 ($580,000) each.


The TU 523 could land vertically on cargo containers to pick them up quickly


Formula 1 teams use nitrogen-filled tyres to ensure grip can be calculated precisely

Filling tyres with nitrogen

How taking inspiration from Formula 1 can improve your drive

While we typically fill our car tyres with regular air, Formula 1 teams and even airlines fill their vehicles' tyres with pure nitrogen. They do this to boost performance and reliability, so should we be doing the same?

The air you pump into your tyres is actually mostly nitrogen anyway – 78 per cent of it to be exact – but it's the other 22 per cent that is the problem. Less than one per cent is water vapour, which at very low temperatures, such as those at high altitudes, and very high temperatures, such as those created when driving very fast, can freeze or expand to make the tyre pressure unstable. For normal driving though, this shouldn't be a problem, so dryer nitrogen won't make much difference.

However, air is also 21 per cent oxygen, and as oxygen molecules are so small, they leak through the tyre rubber over time. Nitrogen molecules on the other hand, are bigger, so they stay inside the rubber for longer and mean you have to get the tyres pumped less often.


Filling your tyres with nitrogen will keep them pumped up for longer

The mechanics of mountain bikes

The incredible tech powering your off-road adventures

Bicycles are remarkably efficient modes of transport. Just look at a typical car, which converts petrol into motion via combustion: only around 20 to 25 per cent of that fuel will be transformed into useful kinetic energy, while the rest ends up as waste heat and pollutants. Compare that to the 90 per cent efficiency that a typical bike derives from the driving force of your legs. But just like motorised vehicles, a bike specialised for a Tour De France-style road race or cruising along a flat promenade, will be very different from those designed for a rough, off-road track.

The rigours of off-roading – which include uneven terrain, wet and slippery mud and wild inclines – mean that mountain bikes need to be much more robust than other types of bike. It's easy to spot the differences when a mountain bike and a road bike, for example, are side by side. Mountain bikes will have much wider tyres – three or four times the width of a road bike – with a more pronounced grip. The bike will feature front and sometimes rear suspension, often twice the number of gears, a thicker frame and a disc brake system. Even a bad cyclist on a road bike could outpace a person riding a mountain bike on flat, even terrain because road bikes are so much lighter and their tyres are smoother. But in unforgiving, off-road conditions, a mountain bike is in its element.

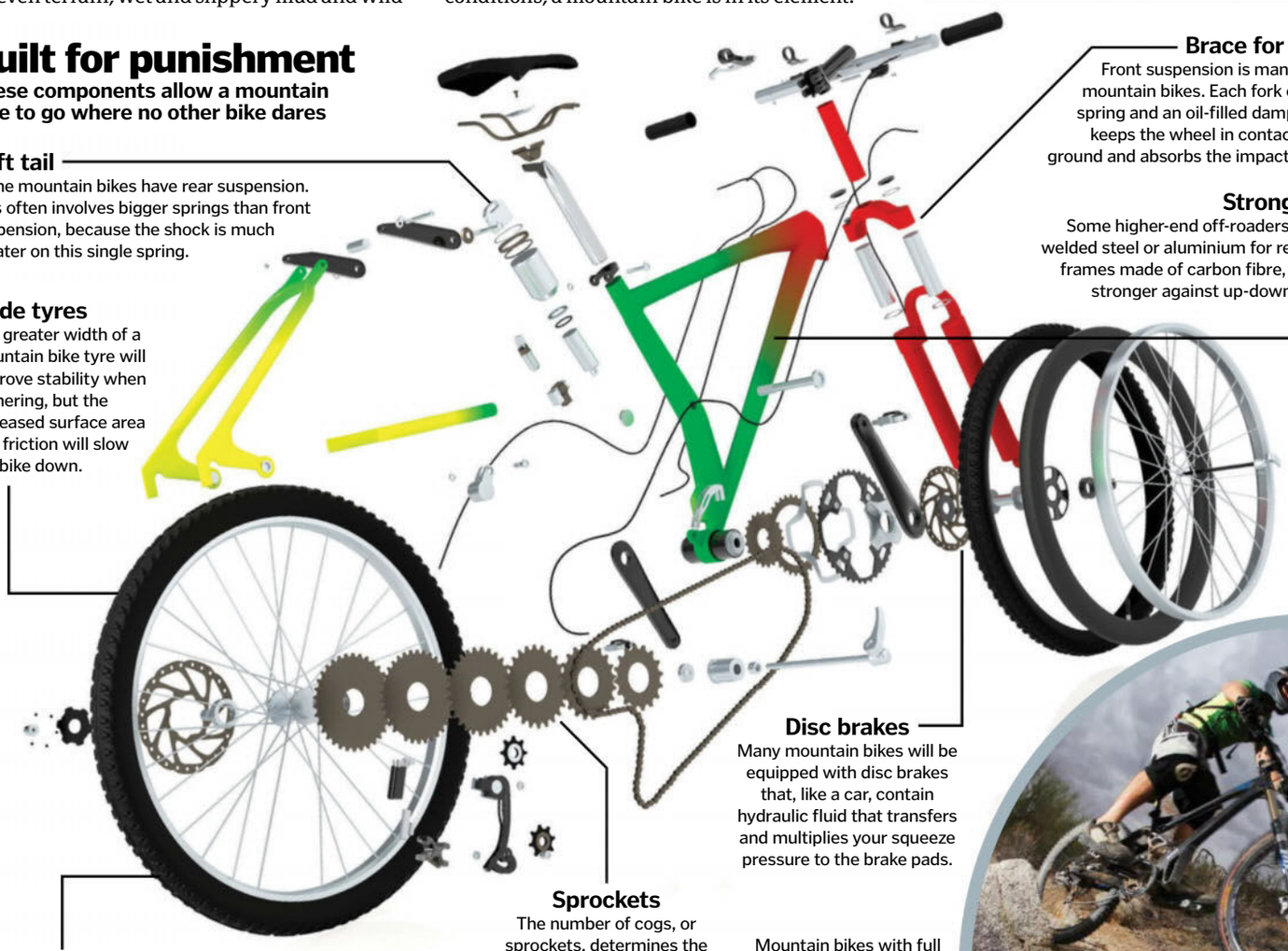
Gear up to go

The pace at which you can turn the pedals will be dictated by the incline your bike is on. Obviously, this is going to be a lot more difficult cycling uphill than on a flat surface, so mountain bikes incorporate a number of different-sized sprockets – or cogs – to produce a gear ratio that will allow you to ride more comfortably. A 27-speed gearing system, for example, will incorporate three sprockets at the back and nine at the front. Changing the gear ratio will allow you to cover more or less ground while maintaining the same pace, so tackling a steep incline or taking advantage of a downhill is never out of the question.

Mountain bikes typically have 21, 24 or 27 gears, compared to the 11 of a road bike

Built for punishment

These components allow a mountain bike to go where no other bike dares



Soft tail

Some mountain bikes have rear suspension. This often involves bigger springs than front suspension, because the shock is much greater on this single spring.

Wide tyres

The greater width of a mountain bike tyre will improve stability when cornering, but the increased surface area and friction will slow the bike down.

Lugging weight

The knobs on a tyre, or 'lugs', dig into loose dirt and mud to provide extra grip.

Sprockets

The number of cogs, or sprockets, determines the number of gears a bike has and thus, the variety of terrain it can tackle.

Disc brakes

Many mountain bikes will be equipped with disc brakes that, like a car, contain hydraulic fluid that transfers and multiplies your squeeze pressure to the brake pads.

Strong frame

Some higher-end off-roaders will forgo welded steel or aluminium for rectangular frames made of carbon fibre, which are stronger against up-down stresses.

Brace for impact

Front suspension is mandatory for mountain bikes. Each fork contains a spring and an oil-filled damper, which keeps the wheel in contact with the ground and absorbs the impact of jumps.

Mountain bikes with full suspension are ideal for rough terrain, as they help to absorb impact

THE SCIENCE OF SUPERPOWERS

Revealed: The real-life physics behind flight, speed and super strength

Superheroes are special because they are more than human. Their bodies can do things that we could only dream of, and they have access to technology that is years or even centuries ahead of our own. But they were written by people with their feet planted firmly in reality, and if you look hard enough, some of their powers are not as impossible as they first seem.

The first DC comic was printed in 1935, and Marvel's debut offering followed soon after in 1939. At the time, the first programmable computer had only just been invented, we didn't know the structure of DNA, and the mobile phone was still decades away.

Since then, science and technology have started to catch up with the stories, but are all superpowers within our grasp? Join us as we explore the science of superheroes, and find out which laws of physics have to be broken to allow our favourite characters to perform their signature moves.

"Batman's suit is made from Kevlar, which is widely used to protect military personnel"

COULD BATMAN'S TECH EXIST?

The protector of Gotham City is just a man, but are his skills and technologies within reach?

Most of Batman's abilities are the result of an arsenal of gadgets, and many are within our grasp. Take his motorcycle, for example; it has a stealth mode that enables it to disappear from view, and incredibly, there is already technology that can do something similar.

BAE Systems is developing a camouflage material known as ADAPTIV. When viewed through an infrared camera, the special panels mask the normal heat signature of military vehicles like tanks, replacing it either with signals that match the background, or with heat patterns that match other objects, like small cars or even cows.

Batman's suit is also grounded in reality. In the Christopher Nolan trilogy, his armour was fashioned from Kevlar – a synthetic material widely used to protect military and law enforcement personnel. When a bullet hits the vest, it tries to force through the layers, but it cannot push the fibres apart because they are tightly woven. The fibres absorb the energy of the bullet by stretching a small amount.

The US Air Force has even developed what they're calling the 'Battlefield Air Targeting Man-Aided kNowledge', or Batman. This programme will test innovative wearable devices for Special Forces to take into combat.

Surviving a fall (or not)

The maths doesn't always work out well for Batman

Higher jump
Students from the University of Leicester calculated that jumping from a 150m building with his cape outstretched would allow Batman to glide for about 350m. However, due to gravity, his impact velocity would be approximately 80km/h, which would be fatal without some serious shock absorption!

At time zero, Batman has travelled no distance

After 0.5 seconds, Batman has travelled 0.5 metres

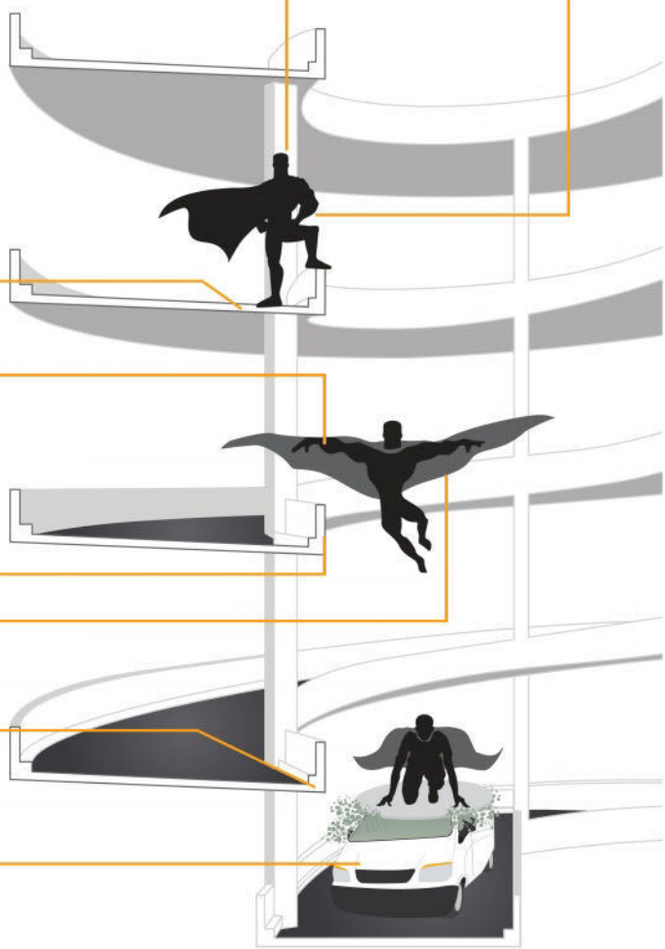
Wingspan
Batman's rigid cape has a wingspan of around 4.5 metres, much smaller than a standard hang glider.

After 1 second, Batman has travelled 5 metres

Drag
The wings create drag, helping to slow Batman's fall.

After 1.5 seconds, Batman has travelled 10.5 metres, and he impacts the floor at 15 metres per second, or 54 kilometres per hour

Impact
In this short jump, and without accounting for his wings, Batman would hit the car at 54km/h. Due to drag, his cape would reduce this speed.



Falling forces

EQUATION

$$\text{Time} = \sqrt{\frac{2 \times \text{Distance travelled}}{\text{Acceleration due to gravity}}}$$

$$\text{Velocity} = \text{Acceleration due to gravity} \times \text{Time}$$

We can estimate Batman's landing speed with a simplified model that discounts the effects of air resistance. Earth's gravity will cause Batman to accelerate towards the ground at 9.8 metres per second, so measuring the distance, you can find out how fast he will be travelling on impact. If his wings are extended, the acceleration will be less than expected because of drag.

Batman is an extraordinary human with access to superhuman technology

SUPER STRENGTH

How Superman's powe could theoretically work

Superman was born on Krypton, a plane massive and denser than the Earth. As a result, his bones and muscles are genetically adapted to withstand a greater gravitational pull. But could this explain his superpowers?

When human astronauts visited the Moon, they found that they could lift heavy objects with little effort and leap several metres in one bound. The idea is that Superman's experience on Earth – a relatively low-gravity environment for him – should be much the same. However, space travel takes its toll on the human body. Astronauts often experience problems with blood flow because the circulatory system is adapted to pump blood against Earth's gravitational pull, and muscle and bones start to waste away due to being underused.

Even if Superman were able to maintain his strength, there are still several aspects of his powers that science cannot explain. He must have travelled faster than the speed of light to arrive on Earth from Krypton as an infant; he is able to balance large structures above his head without them crumbling at the edges; and bullets bounce off his chest.

The latest films allude to the idea that his real superpower is in fact gravity control. According to Einstein, gravity is actually the result of distortions in the fabric of space-time. In theory, if Superman could manipulate this fabric, he would be able to change direction in mid-air, deflect bullets, and travel through time.

Skin-tight suit
The iconic outfit may be more than just streamlined. Super-tight clothing can actually limit muscle damage and improve recovery – useful if you're stopping a plane in mid-air.

X-ray vision
Humans can't see X-rays because the receptors in our eyes are unable to detect such high-energy wavelengths.

Understanding gravity

EQUATION

$$\text{Time} = \text{Gravitational constant} \times \frac{\text{First mass} \times \text{Second mass}}{(\text{Distance between centres of masses})^2}$$

Every mass attracts every other mass, and the resulting force is known as gravity. Newton showed that the force increases as the mass of either object increases, and that it decreases as the distance between them gets bigger. According to Einstein, gravity is actually not a force at all.

How lightning strikes

In clouds, small droplets of water or ice can collide with each other as they rise through the atmosphere, knocking off electrons as they do so. The positively charged molecules continue to rise, while the negatively charged electrons settle in the lower part of the cloud. The build-up of electrical charge in the cloud becomes so large that the negatively charged cloud base actually repels electrons in Earth's surface. This electric field eventually becomes strong enough to ionise the air in between, so that current can flow between the positive ground and the negative cloud, which we see as lightning.

CREATING A STORM

Marvel Comics' Storm has command of the elements, and can discharge lightning bolts at will. If these were anything like the real thing, they would each deliver around 10 billion watts of energy; that's enough to power more than 50 houses for an entire day.

Rather than discharge this energy, Storm uses psychic abilities to manipulate weather. If she had control of atmospheric temperature, she would be able to alter the flow of air to create the conditions needed for extreme weather, such as hurricanes and blizzards.

For lightning, this would involve generating updrafts and downdrafts so that particles rub past one another, leaving their electrons behind and creating a build-up of charge.

SUPER SPEED

Would The Flash survive if it were possible to run at the speed of light?

If he were to travel at the speed of light, The Flash could get to the Moon and back in under three seconds, but reaching the 299,792-kilometre-per-second speed limit of the universe would defy physics. Assuming, however, that he is able to come close to this maximum speed, could The Flash really survive such rapid travel?

The first challenge is drag; as The Flash moved through the atmosphere, he would collide with gas and dust particles. The faster he went, the more he would disturb the air, and the more drag he would experience. Moving at such high speeds would also compress the air in front of him, because it just wouldn't have time to get out of his path. Both the friction and air compression would generate heat, even when travelling at relatively low speeds. For example, the surface of a Soyuz capsule re-entering the Earth's atmosphere at about 230 metres per second (over 1.3 million times slower than the speed of light) can reach blistering temperatures of 1,650 degrees Celsius.

The Flash would also struggle with reaction speeds. The fastest human nerves can send messages at speeds of around 100 metres per second, but for someone travelling close to the speed of light, thousands of kilometres would go by before there was time to perform even simple movements.

So how does he do it? The Flash is said to use the 'Speed Force' to accelerate, which confers many abilities on other superheroes, including boosts to endurance, perception, advanced healing and decelerated ageing. Perhaps, rather than super speed, The Flash actually has the ability to manipulate time.

EQUATION

What does relativity have to do with superheroes?

$$\text{Energy} = \text{Mass} \times (\text{Speed of light})^2$$

Einstein's famous equation shows that an object's energy is equal to its mass multiplied by the speed of light squared. This means that if you add energy, you also add mass – so as the Flash speeds up, he gets heavier.

Speed limits

The Flash is fast, but physics prevents him from breaking through the speed of light

Acceleration
You need to add energy if you want a particle with mass to accelerate.

More energy
The more massive a particle is, the more energy is needed to accelerate it.

Infinite energy
As a particle approaches the speed of light, it becomes infinitely more massive, and requires an infinite amount of energy to carry on accelerating.

Speed limit
Mass-less particles, like photons, move at the fastest possible speed: the speed of light.

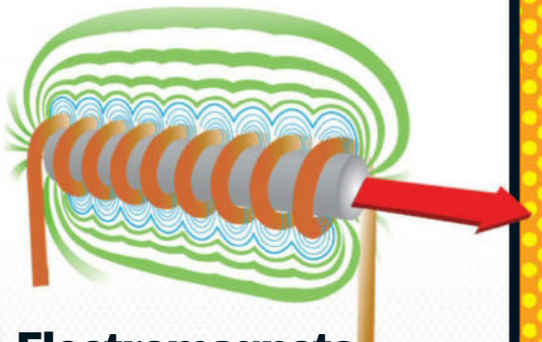
Magneto has control of the electromagnetic force, one of the four fundamental forces

MAGNETIC POWERS

Magneto is a Marvel mutant with magnetic powers, but he does more than just manipulate iron. He can levitate, read minds, and control technology.

If Magneto has control of magnetism, he must also have control of electricity; they are both the result of electromagnetic forces, produced by the interaction between charged particles.

By manipulating magnetic fields, Magneto would have no trouble lifting metal objects into the air, and even organic life forms would be possible. Water molecules are diamagnetic, which means that when a magnetic field is applied, water tries to oppose it, by creating an induced magnetic field in the opposite direction. Diamagnetism is very weak, but with a strong enough magnet, this property can be used in real labs to levitate frogs.



Electromagnets

Since electricity and magnetism are linked, a current flowing through a wire generates a magnetic field. Electromagnets can be created by wrapping a coil of conductive wire around an iron core, and passing a current through the wire. This principle can be exploited to create very powerful magnets, with the benefit of being able to switch them on or off when needed.

ANIMAL ABILITIES

Spider-Man's silk is inspired by the stronger-than-steel threads made by real spiders

Spider silk might look fine and delicate, but weight for weight, it is stronger than steel. It can stretch 30 per cent more than its original length, and can withstand the same pulling force of a thread of steel five times its thickness. It is estimated that a spider silk strand the same thickness as a pencil would be able to bring a Boeing 747 jumbo jet to a standstill mid-flight.

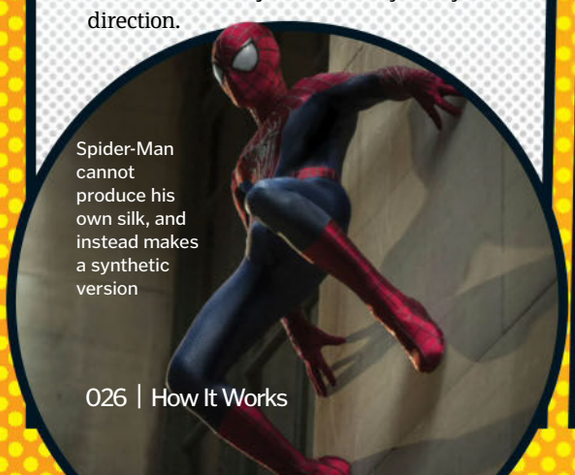
Real spiders produce several different kinds of silk, each with a different use, including attaching threads that can be secured to other objects, non-sticky 'dragline' threads for dangling, and swathing silk for wrapping.

Biologists have managed to use genetic engineering to transfer some of the genes for making spider silk into goats so that they

"Like a real spider, Spider-Man stores his silk as a liquid"

produce silk proteins in their milk. However, Peter Parker did not acquire the ability to make his own when he was bitten. Instead, he designed wrist-mounted web shooters to produce strings of synthetic silk, made from a stretchy nylon-like polymer. Like a real spider, Spider-Man stores his silk not as pre-made threads, but as a liquid that can be formed into strings on demand.

There is one key difference though. For a real spider to produce silk, the thread needs to be pulled, either by their own weight as they descend, or by the wind as they send threads across gaps to build their webs. Spider-Man, on the other hand, can shoot his webs, pushing them out and away from his body in any direction.



Spider-Man cannot produce his own silk, and instead makes a synthetic version

THE NIGHT GWEN STACY DIED

Was it the webbing or the fall that killed Spidey's squeeze? Physics has the answer

In a pivotal moment of comic book history, Peter Parker's love interest, Gwen Stacy, was pushed off a bridge by the Green Goblin (The Amazing Spider-Man, Issue #121-122, Marvel Comics). In an attempt to break her fall, Spider-Man shoots a line of webbing. Caught on the web, he thinks that Gwen is safe, but when he pulls her up he finds her dead. One argument for why she died is that the sudden stop was too much for her neck to handle. The Green Goblin claims that Gwen died during the fall, but it is the stop, not the fall itself, that is dangerous.

© Marvel

Acceleration
Gwen starts off with zero velocity and accelerates toward the ground due to gravity. Within just a few seconds she is falling at a very high speed.

Breakneck speed
If we assume air resistance is negligible, by falling just 90m (half the height of the bridge) she would reach a speed of around 140km/h.

Bounce back?
If Spider-Man's silk had behaved like the real thing, it might have been elastic enough to slow Gwen gently.

Elastic
The strongest form of spider silk, known as dragline silk, would be elastic enough to make bungee cord.

Quick change
As Spider-Man's webbing catches her, Gwen is brought to a sudden stop. If she were to go from travelling at 140km/h to 0km/h in just half a second, she would experience a force of approximately 8 g (roughly the same as a fighter jet pulling out of a dive).

Deadly force
Changing velocity so quickly generates forces that are too much for Gwen Stacy's neck to handle.

Why did Gwen die?

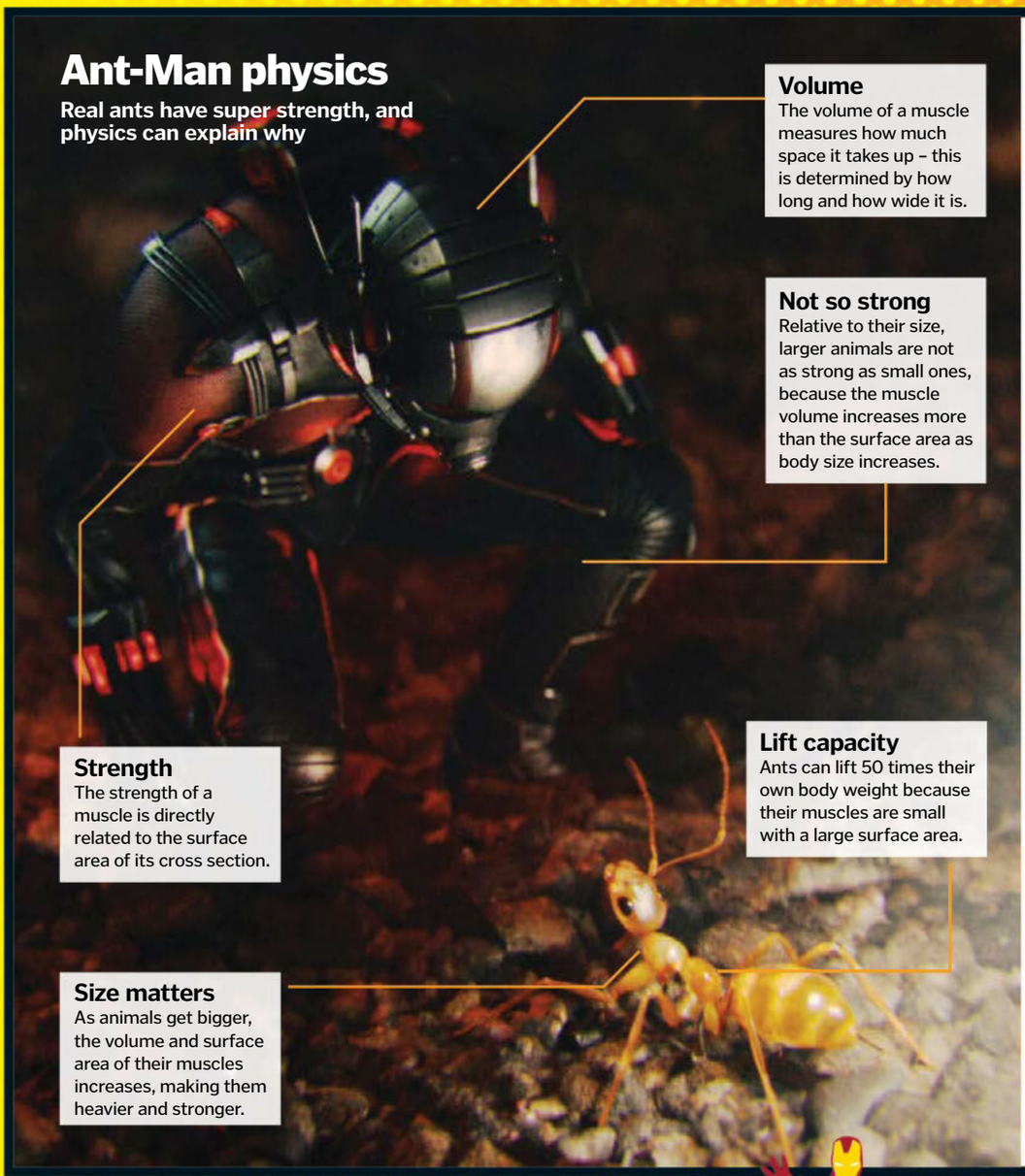
EQUATION

Impulse = Average force x Collision time
= Mass x Change in velocity

The impact force of a collision is related to the mass of the object and its velocity, and can be changed by altering the collision time. Hitting the ground and coming to a dead stop results in maximum force, while slowly stopping would result in a much less violent impact. This is the basis behind parachutes, crumple zones in cars, and buffers on railway tracks.

Ant-Man physics

Real ants have super strength, and physics can explain why



Volume
The volume of a muscle measures how much space it takes up – this is determined by how long and how wide it is.

Not so strong
Relative to their size, larger animals are not as strong as small ones, because the muscle volume increases more than the surface area as body size increases.

Strength
The strength of a muscle is directly related to the surface area of its cross section.

Lift capacity
Ants can lift 50 times their own body weight because their muscles are small with a large surface area.

Size matters
As animals get bigger, the volume and surface area of their muscles increases, making them heavier and stronger.

SUPER SMALL, SUPER STRONG

Does the real-life Higgs Boson act like Ant-Man's Pym particles?

The man behind Ant-Man's amazing abilities is Dr Henry 'Hank' Pym, a fictional scientist who discovers subatomic 'Pym particles', capable of altering the size and mass of any object. Impossible? Yes, but there are actually some parallels in real-world science.

In 2012, scientists at CERN in Switzerland announced that they had discovered the Higgs boson. It is an elementary particle, thought to be evidence of the existence of something known as the Higgs Field. The field is everywhere, and is responsible for giving other particles their mass.

We cannot manipulate the Higgs Field to change the mass of subatomic particles, and it does not affect their size, but the fictional Pym particles could work in a similar way. If Pym particles had an associated Pym Field that could make particles smaller, and Dr Pym managed to find a way to manipulate it, he might be able to shrink himself down to miniature size.

SUPERHUMAN SUITS

The military exoskeletons that enhance soldiers' natural strength

While modern powered exoskeletons are nowhere near as super as Iron Man's, they do enable superhuman feats of strength. The XOS 2, made by Raytheon, is an experimental military exoskeleton that allows the wearer to lift more than their own body weight without tiring. It does this using hydraulics, joints, sensors and motors that control a strengthened steel and aluminium frame.

Real exoskeletons are powered by fuel cells or internal combustion engines, but nothing can compare to the miniature Arc Reactor that keeps Iron Man's suit operational. The closest thing we have are tokamaks; experimental fusion reactors first developed by the Soviet Union during the Cold War. They are doughnut-shaped, and contain hot plasma held in place by a powerful magnetic field. The idea is that within the reactor, atoms should fuse, releasing energy in the same kinds of reactions that power the Sun, but so far this has not been viable.

Tony Stark quickly abandons using iron in his suit in favour of more lightweight materials

"The closest thing to the Arc Reactor is an experimental fusion reactor called a tokamak"

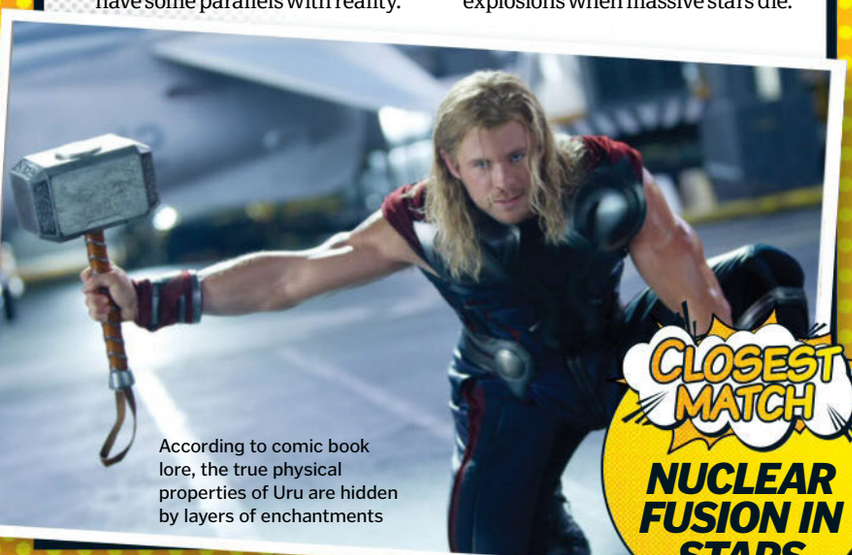
SUPERHERO SUPERMATERIALS

Which real-life materials come close to the awesome properties seen in comic books?

URU

This metal ore is found only in Asgard, the home of the Norse gods. It can withstand extremes of force and temperature, has an unusual affinity for magical enchantments, and was used to create Thor's famous hammer, Mjolnir. Although it sounds far-fetched, the story does have some parallels with reality.

Inside the nuclear reactor at the centre of a star, atoms smash together with such force that their nuclei fuse, forming heavier elements with different properties. All of the natural metallic elements we know were created inside these stellar forges, or in the dramatic explosions when massive stars die.



According to comic book lore, the true physical properties of Uru are hidden by layers of enchantments

CLOSEST MATCH

NUCLEAR FUSION IN STARS

KRYPTONITE

Kryptonite is the ore of a radioactive element found on Superman's home world, Krypton. Despite the name, it has no relation to the real element, krypton – a noble gas that glows white when an electrical current passes through it.

The chemical composition of kryptonite, described in the film *Superman Returns*, is sodium lithium boron silicate hydroxide with fluorine, and incredibly, in 2007, scientists reported that they had discovered a material with a similar chemical composition.

Known as jadarite, the real-world mineral does not contain fluorine and is not radioactive. It is white in colour, and glows red-orange when exposed to ultraviolet light.

The closest thing to Kryptonite is not radioactive and is white in colour

CLOSEST MATCH

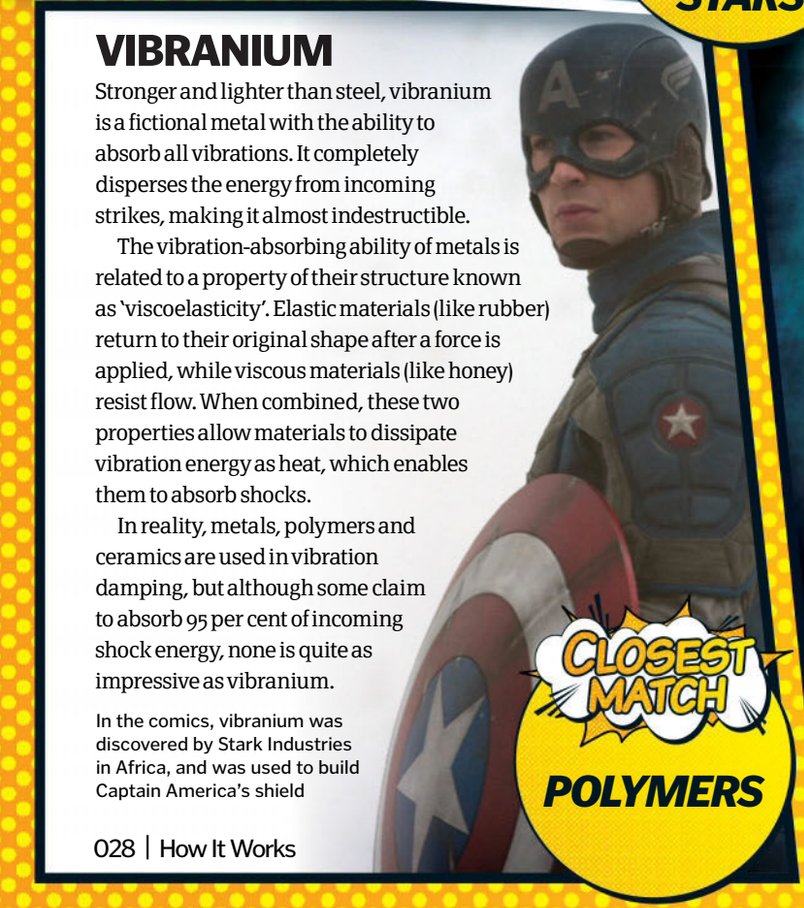
JADARITE

VIBRANIUM

Stronger and lighter than steel, vibranium is a fictional metal with the ability to absorb all vibrations. It completely disperses the energy from incoming strikes, making it almost indestructible.

The vibration-absorbing ability of metals is related to a property of their structure known as 'viscoelasticity'. Elastic materials (like rubber) return to their original shape after a force is applied, while viscous materials (like honey) resist flow. When combined, these two properties allow materials to dissipate vibration energy as heat, which enables them to absorb shocks.

In reality, metals, polymers and ceramics are used in vibration damping, but although some claim to absorb 95 per cent of incoming shock energy, none is quite as impressive as vibranium.



In the comics, vibranium was discovered by Stark Industries in Africa, and was used to build Captain America's shield

CLOSEST MATCH

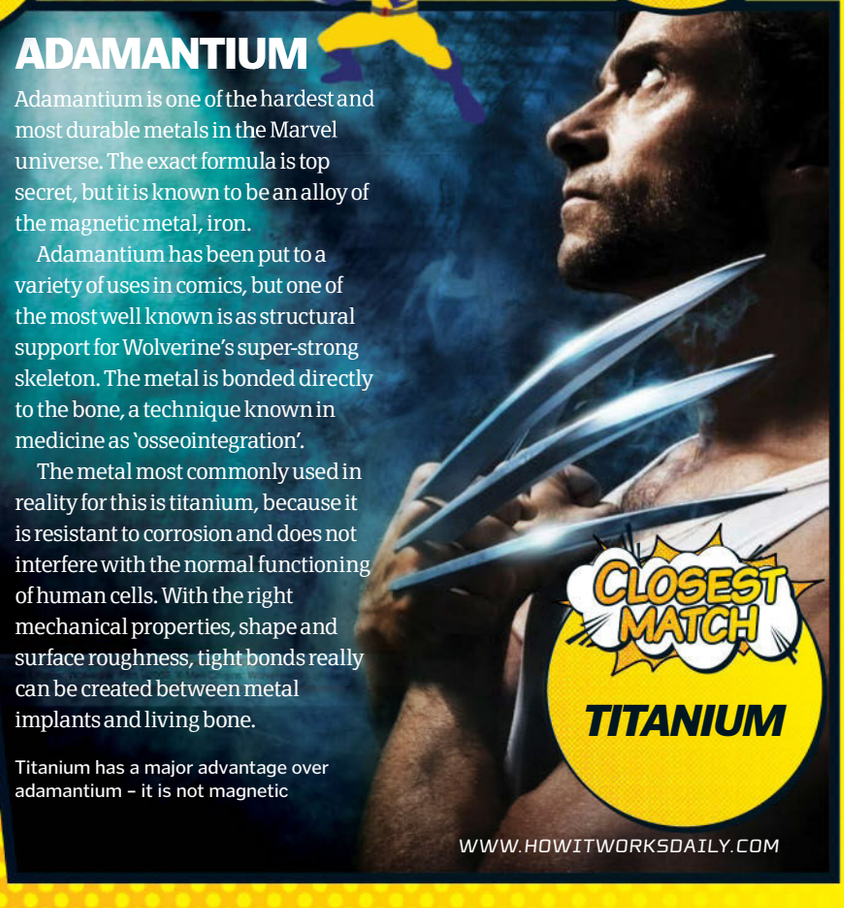
POLYMERS

ADAMANTIUM

Adamantium is one of the hardest and most durable metals in the Marvel universe. The exact formula is top secret, but it is known to be an alloy of the magnetic metal, iron.

Adamantium has been put to a variety of uses in comics, but one of the most well known is as structural support for Wolverine's super-strong skeleton. The metal is bonded directly to the bone, a technique known in medicine as 'osseointegration'.

The metal most commonly used in reality for this is titanium, because it is resistant to corrosion and does not interfere with the normal functioning of human cells. With the right mechanical properties, shape and surface roughness, tight bonds really can be created between metal implants and living bone.

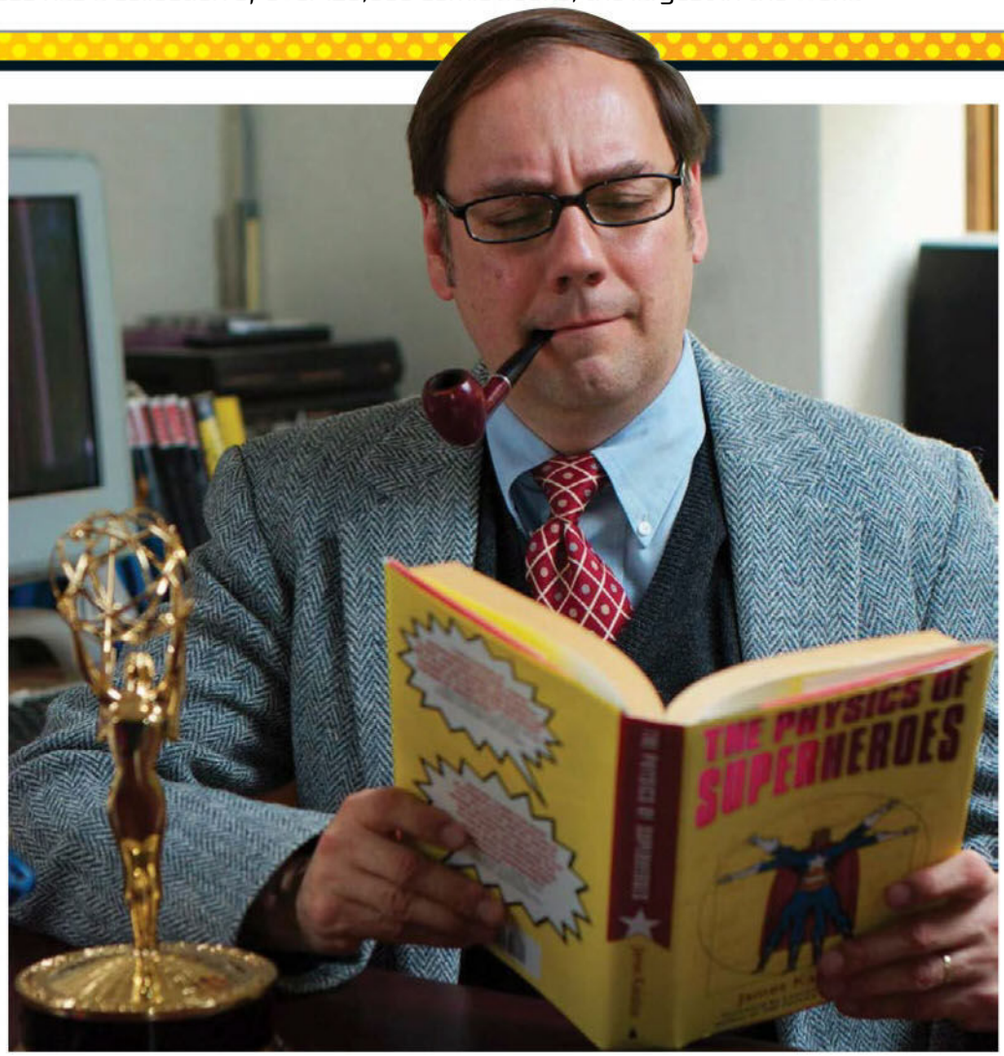


Titanium has a major advantage over adamantium – it is not magnetic

CLOSEST MATCH

TITANIUM

WHEN PHYSICS AND COMICS COLLIDE



Jim Kakalios is the author of The Physics of Superheroes and Professor at the School of Physics and Astronomy at the University of Minnesota

How did you get into using superheroes to explain physics?
It actually started when I was teaching just a regular introductory physics class, and I was trying to come up with an example that dealt with momentum and forces that hadn't been done a hundred times before.

Being not just a college professor, but also a comic book aficionado – which makes me simultaneously a nerd and a geek, sorry ladies, already married – it occurred to me that the death of Spider-Man's girlfriend Gwen Stacy, as portrayed in Amazing Spider-Man number 121, would be a perfect illustration.

I did a little calculation, I saw that it all worked out, I put it on an exam, and the students responded very positively to applying their physics principles to a situation that was taken from a comic book.

Which of the superheroes breaks the most scientific rules?
Pretty much anyone that involves violations of conservation of energy or mass in order for their powers to work. The Flash, who can run at super speed, if you figure out how much he would need to eat, it's something like 200 million cheeseburgers every time he wants to run!

Are any of the superheroes within reach?
I would have to say that perhaps the most realistic might be someone technologically based, like Iron Man. Most of the technologies that he employs are things that we have right now. The big exception is the power supply. In the 2008 Marvel movie, *Iron Man,* Tony Stark has built a power supply for his suit that is about the size of a hockey puck, and puts out the power of three nuclear power plants. If we knew how to do that, we wouldn't need superheroes!

"The Flash would need to eat 200 million cheeseburgers to run!"

What is your favourite piece of technology from a comic book?
In the comics, when Iron Man wants to activate his boot jets, or fire his repulsor rays, you don't see him press a button, you don't see him flip a switch, or even give a voice command. He just thinks it, and it happens. In the comic books, this was explained by Iron Man's cybernetic helmet that picks up his thought waves. If he's thinking "fire repulsor ray in my right glove", it happens. This is accurate. This is real.

Departments of Biomedical Engineering and Neuroscience at the University of Minnesota, and at many other universities, are developing cybernetic helmets. In your brain, when you're thinking, there are weak electrical currents, and these generate very weak electromagnetic waves, about a billion times weaker than radio. But if you put the detectors right on your head, and you have amplifiers to boost the signal, you can transfer it wirelessly to a computer.

Once the system has been trained, and knows how to interpret what that signal represents, it can then send that information to some other device; a remote-controlled helicopter, or a prosthetic device.

If you were inventing a real superhero, grounded in real science, what would their power be?
Our superpower is our intelligence. It has enabled us to become the dominant species on the planet. We can adapt the planet to us. Having a superpower doesn't make you a hero; it's what you do with it.

If you thought 50 years ago that you would have the collective wisdom of the planet available to yourself, instantaneously – it would be very hard to imagine. We talk about Superman and X-ray vision, but we have magnetic resonance imaging where we can see inside the body without a cut of a knife. I searched through old 1930s science fiction pulp magazines to try and find someone predicting MRI, and I couldn't find anything.

What we have managed to do has just been so fantastic. One thing I know from reading sci-fi and comic books is that trying to predict the future is a mug's game.

Read the full interview at www.howitworksdaily.com.

© REX; Getty

Know your nerve cells

Take a closer look at the cells that send signals around your body

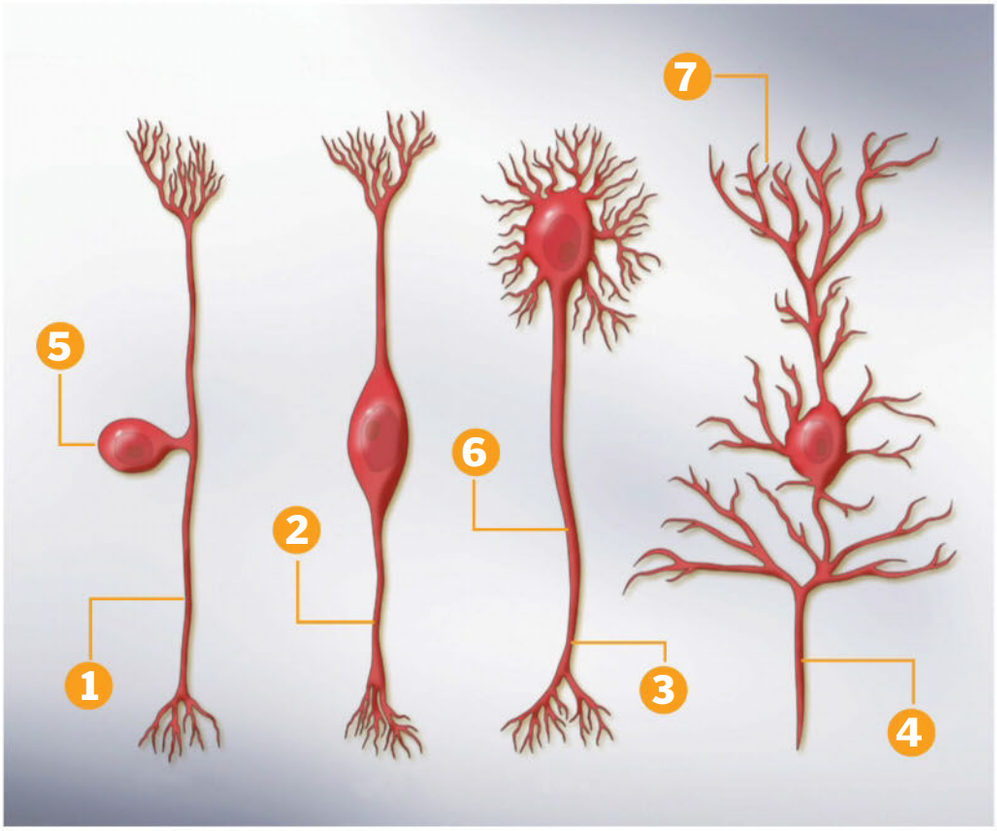
Nerve cells, or neurones, are the electrical wiring of the human body. They all have some key features in common, but depending on their specific role, they also have their own specialisms. In fact, there are more than 200 different types.

Many nerve cells can be broadly divided into four categories depending on their shape: pseudo-unipolar, bipolar, multipolar, and pyramidal. These categories are based on the number of spindly extensions that stick out from the cell body, the centre of the cell. This contains the nucleus, which carries the genetic instruction manual, and houses everything the nerve cell needs to produce the molecules that do its job. The projections link one nerve cell to the next, carrying messages in the form of electrical signals, and passing them on using chemical messengers called neurotransmitters.

There are two main types of projection. Axons are often long and tube-shaped, and carry messages away from the cell body, while dendrites are more often short and tapered, and usually receive signals from other nerve cells.

Types of neurone

The main functions of these highly specialised cells



1 Pseudo-unipolar
These cells have one projection that divides into two. The cells often transmit sensory signals.

2 Bipolar
These cells have two projections. They connect one nerve cell to the next in the brain and spinal cord.

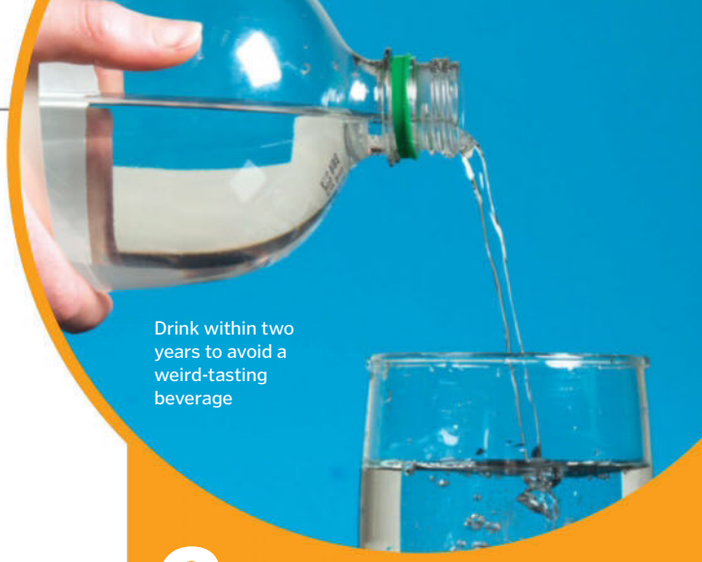
3 Multipolar
These cells have one long projection and lots of smaller ones. They send signals to the muscles.

4 Pyramidal
These cells have lots of branching projections. They are only found in parts of the brain.

5 Cell body
The cell body is the control centre of the cell and it produces all of the proteins the cell needs.

6 Axon
There is just one axon per nerve cell. Its job is to carry electrical signals away to other cells.

7 Dendrites
Each nerve cell has hundreds or thousands of dendrites. They receive signals from other cells.



Drink within two years to avoid a weird-tasting beverage

Can bottled water go bad?

Find out why there's an expiration date on a product that won't spoil

The foods that we buy have expiration dates because they contain sugars and proteins that are broken down by microbes over time, which makes them 'go off'. However, pure water (that doesn't contain any added flavourings or additives) has no sugars or proteins and so technically, microorganisms can't break down when it's in a sealed container. Without being exposed to any microbes and bacteria in the air, completely sealed bottled water would remain in a stable state.

However, there are often sell-by or use-by dates stamped on the packaging to advise consumption within two years. This is because the plastic bottles that store the water aren't totally impermeable, meaning that, over time, some molecules from the bottle itself and the surrounding environment are able to leach into the water. Because of this, if left for too long in unfavourable storage conditions (for example in strong heat or light, or around strong chemicals or odours), the water may take on an unusual taste due to the different mixture of molecules inside.

Once opened, bottled water should be consumed within a few days, particularly if you have taken a drink directly from the bottle. Your saliva contains bacteria which can reproduce in the water and contaminate it, potentially making you ill if you reuse the same bottle without washing it thoroughly.

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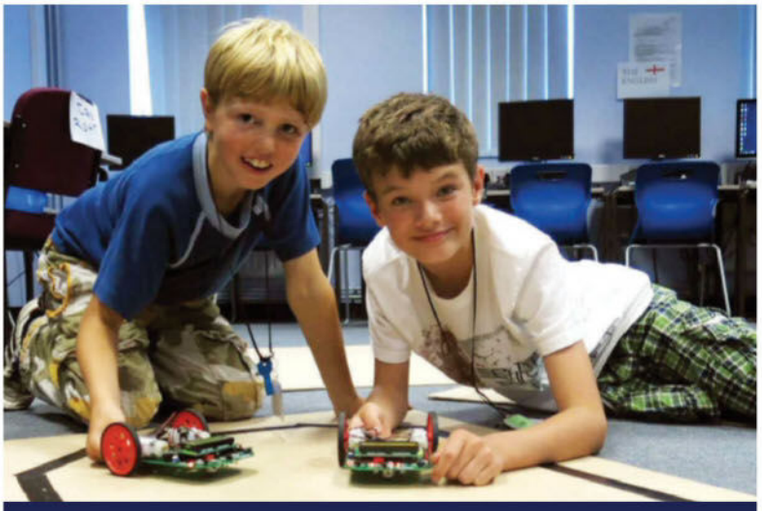

Great Minds Like A Think

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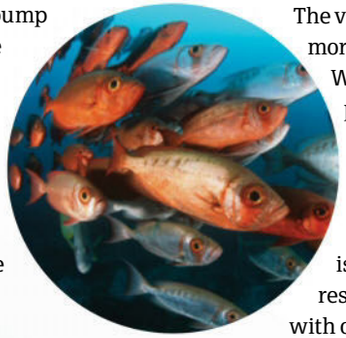
ANIMAL HEARTS

From primitive fish hearts, to complex machines like our own, find out how different creatures get their blood pumping

FISH HEARTS

The job of the heart is to pump blood around the body, collecting oxygen and nutrients, dropping them off in the tissues that need it, and transporting waste products away. One of the simplest ways to do this is to have a single pump that moves the blood around in a loop. This is how a fish heart works.

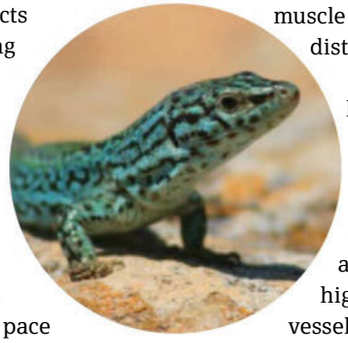


Fish hearts have two chambers. The blood comes into the heart through a tube called the sinus venosus, which contains cells that set the rhythm for the muscle. These send waves of contractions into the heart, forcing the blood through it. The first chamber is called the atrium, and it is responsible for collecting blood that has returned from its trip around the body. As it starts to fill up, the atrium contracts, forcing blood into the second chamber, which is called the ventricle.

The ventricle has thicker, more muscular walls. When it contracts, it pushes the collected blood back around the body at high pressure. The first stop after the heart is the gills, which resupply the blood with oxygen and remove carbon dioxide. As the blood leaves the heart, it passes into a stretchy blood vessel first, which helps to reduce the pressure slightly before the blood reaches the gills. This protects the fine capillaries from damage.

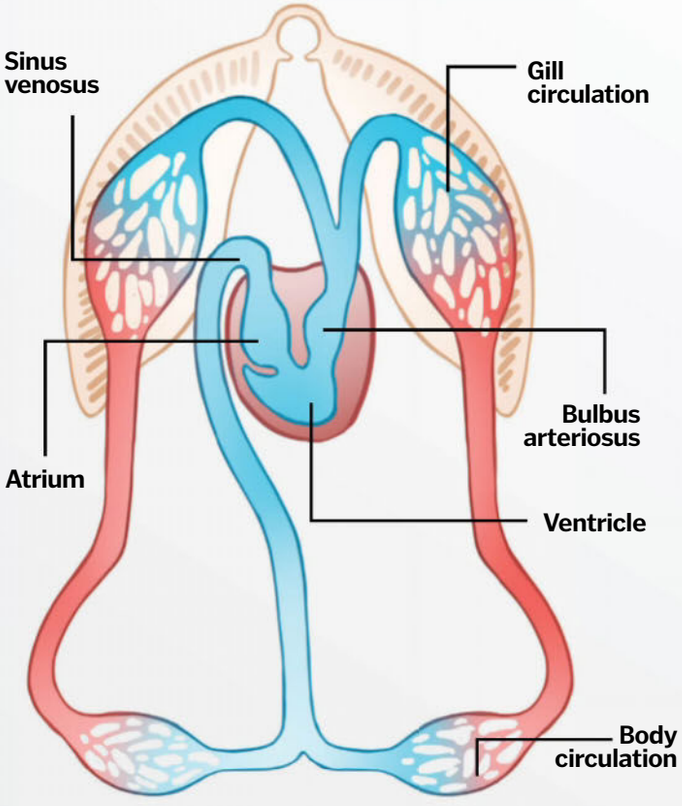
REPTILE HEARTS

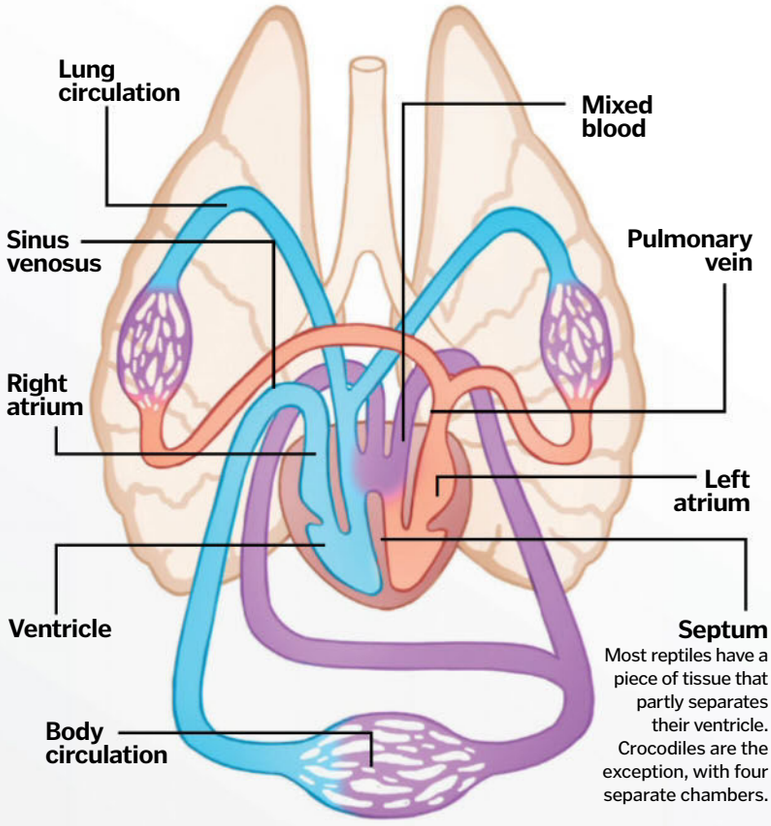
Most reptiles have three-chambered hearts. Like fish, they have just one ventricle, but they have two atria, allowing the two supplies of blood from the body and the lungs to be separated. The right side of the heart collects blood returning from the body.



As with the fish heart, it enters through a structure called the sinus venosus, which sets the pace for the heart by producing rhythmic contractions. This blood has been depleted of oxygen, and contains waste carbon dioxide from the tissues. Oxygen-rich blood from the lungs enters through the pulmonary vein, which comes into the second atrium on the left side. All of this separated blood has to go through one ventricle, but some clever anatomy helps to keep it separated. Inside are ridges of muscle that help to form distinct channels.

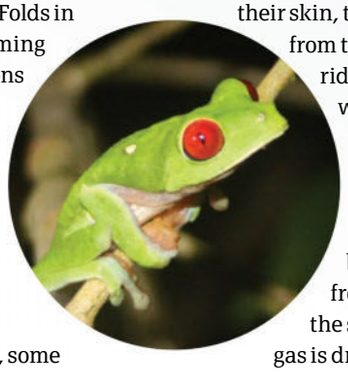
One diverts low-oxygen blood from the right side of the heart to vessels heading towards the lungs, and another diverts high-oxygen blood to vessels leading to the body. Some mixing does occur but reptiles are adapted to cope with this. They are cold-blooded, move slowly, and have a slow metabolism, minimising the amount of oxygen their tissues need.





AMPHIBIAN HEARTS

Like reptiles, amphibians have three-chambered hearts. The layout is similar, with two atria to separate oxygenated blood from deoxygenated, and one ventricle to pump it back out into the body again. Folds in the heart and timing of the contractions help to keep the blood from mixing as it leaves, although it cannot prevent it completely.



As the blood leaves the heart, some is diverted towards the body, and the remainder is sent to pick up more oxygen, but amphibian lungs aren't very efficient. Our lungs contain lots of tiny chambers called alveoli, which result in a huge surface area where gases can dissolve. In contrast, amphibian lungs are like balloons, so the amount of gas they can exchange is very limited. However, amphibians are able to 'breathe' through their skin, taking in oxygen from the air and getting rid of carbon dioxide without using their lungs at all.

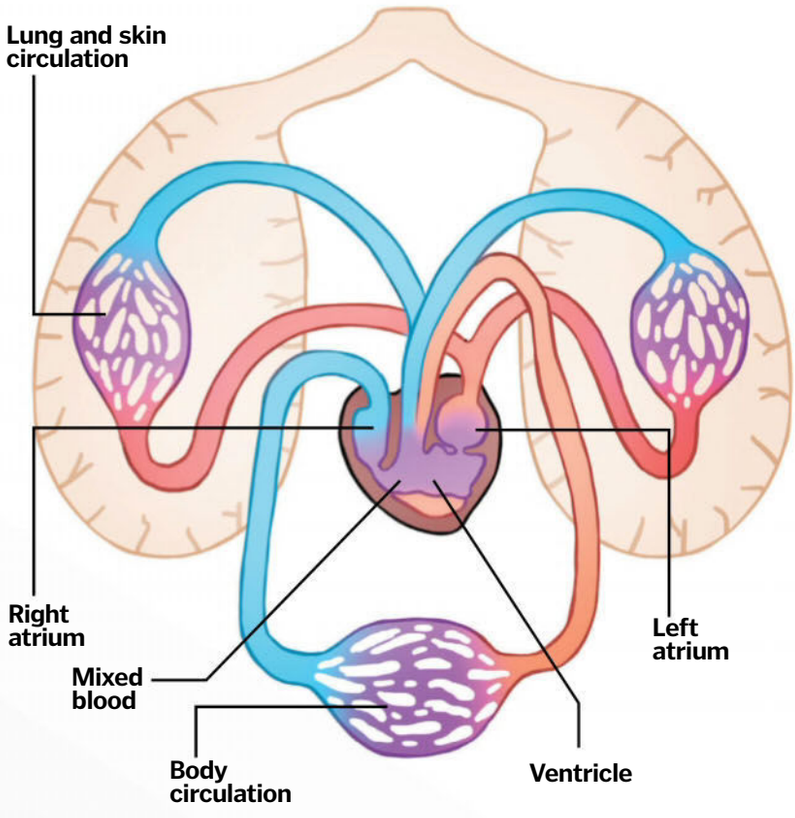
The heart also needs a supply of oxygen, so as blood returns from the lungs and the skin, some of the gas is dropped off. Humans have dedicated blood vessels called coronary arteries to carry out this job, but amphibian hearts beat much slower than our own so they don't need quite as much oxygen to function.

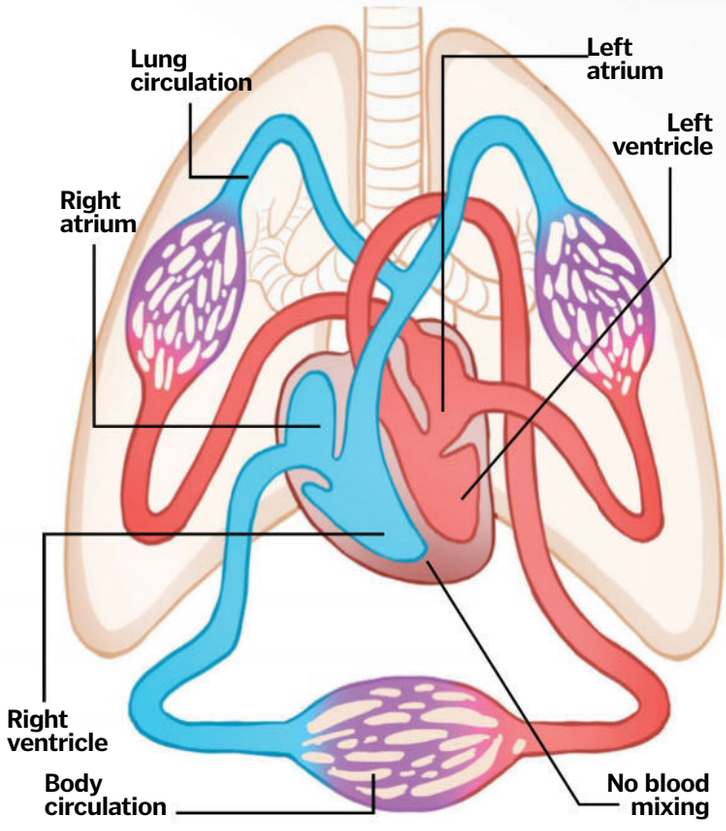
MAMMAL HEARTS

The mammalian heart is separated into two distinct sides; the right collects spent blood and sends it to the lungs, and the left collects fresh blood and sends it to the body. Like amphibians and reptiles, mammals have two atria, but the ventricle has been completely split in two, making separate chambers so that the blood cannot mix.

Birds also have four-chambered hearts. This system is much more efficient than the others, allowing the maximum amount of oxygen to be delivered to the tissues of the body. This allows mammals and birds to be much more active than their counterparts with more primitive hearts, and it also provides the extra oxygen needed to regulate body temperature. Fish, amphibians and reptiles are cold-blooded, and rely on their environment to control their internal temperature. With inefficient hearts and fairly slow lifestyles, this works very well for them.

Birds and mammals, on the other hand, are warm--blooded; we regulate our own temperature and this requires a lot of oxygen. The ability to pump blood more efficiently and to keep our bodies supplied with a constant stream of oxygen allows mammals and birds to live very active lifestyles, and enables us to hunt and run even when it is cold.





How the eye focuses

The tiny rings of muscle that make your vision sharp

Cameras and human eyes both focus light using a lens. This structure bends the incoming wavelengths so that they hit the right spot on a photographic plate, or on the back of the eye. A camera lens is made from solid glass, and focuses on near and distant objects by physically moving closer or further away. A biological lens is squishy, and it focuses by physically changing shape.

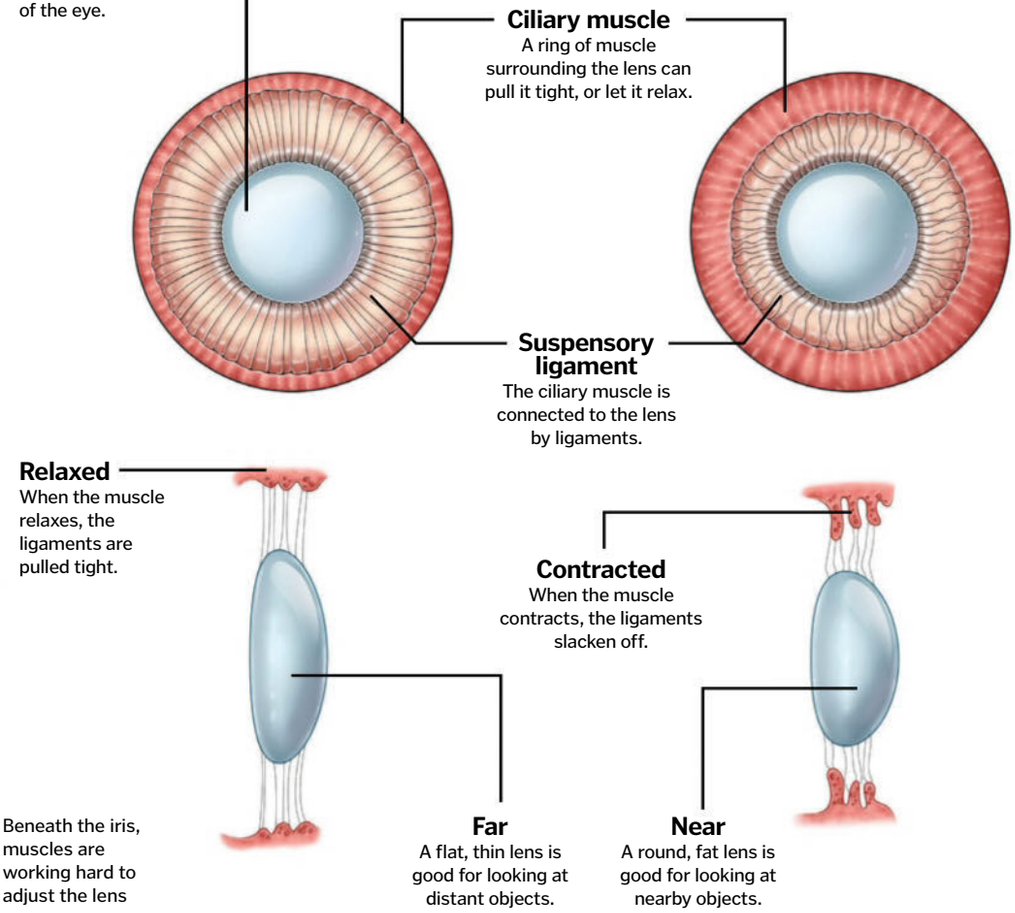
In the eye, this process is known as 'accommodation', and is controlled by a ring of smooth muscle called the ciliary muscle. This is attached to the lens by fibres known as suspensory ligaments. When the muscle is relaxed, the ligaments pull tight, stretching the lens until it is flat and thin. This is perfect for looking at distant objects.

When the ciliary muscle contracts, the ligaments loosen, allowing the lens to become fat and round. This is better for looking at objects that are nearby. The coloured part of the eye – called the iris – controls the size of the pupil and ensures the right amount of light gets through the lens.

Beneath the iris, muscles are working hard to adjust the lens

Accommodation explained

How the lens changes its shape to focus on near and distant objects



How potato batteries work

The science behind the classic spud-power test

Before we begin, don't go ripping out the AA batteries from the TV remote. The key thing to know is that the potato isn't *actually* functioning as a battery – instead, it facilitates the flow of electrons that make up an electrical current.

The setup starts with two rods (called electrodes) stuck into the spud, one copper and one zinc. These are each secured by metal clips to wires, which are connected to the object you are trying to power, such as a voltmeter or a light bulb. When the electrodes come into contact with an acid, a chemical reaction takes place. It's the naturally occurring mild phosphoric acid in potatoes that allows this to happen.

As the zinc electrode, which is negatively charged, touches the inside of the potato, a chemical reaction occurs and electrons are given off. These electrons travel through the wire and are accepted by the positively charged copper electrode. It is this flow of electrons that creates an electrical current.

The voltmeter will show roughly one or two volts, enough to power a small light bulb, buzzer or digital clock. Amazingly, if you boil your potato battery, its electrical capacity increases tenfold!

It's not just veggie power; some fruits can do the same, including lemons

60 SECOND SCIENCE

Laws of thermodynamics

EXPLAINED! THE PHYSICS OF HOW ENERGY FLOWS

BACKGROUND

Energy is what makes everything happen, from getting out of bed to launching a rocket. For these things to occur, there needs to be an energy change - energy must be converted from one form to another. For example, chemical energy from your food is converted into kinetic energy when you move, along with thermal energy, or heat.

Thermodynamics is the branch of physics concerned with the relationship between heat and energy. Its four laws govern what happens in every energy change, and are key to understanding the world around us.

IN BRIEF

The first law of thermodynamics states that energy is always conserved, so the amount put into a system is the same as the amount that comes out. However, while the amount of energy remains the same, its usefulness decreases as it changes form. This is the second law of thermodynamics, and it's the reason why there's no such thing as a 100 per cent efficient machine. In other words, energy can't be recycled and some form of energy will need to be added to keep a machine running.

The 'zeroth' law defines the notion of temperature, while the third law states that a substance cannot reach absolute zero (-273.15 degrees Celsius), as its atoms would have no kinetic energy, which is impossible.

SUMMARY

The laws of thermodynamics explain the relationship between all types of energy. These principles are used to understand how all machines work, from human bodies to steam engines.

The first and second law

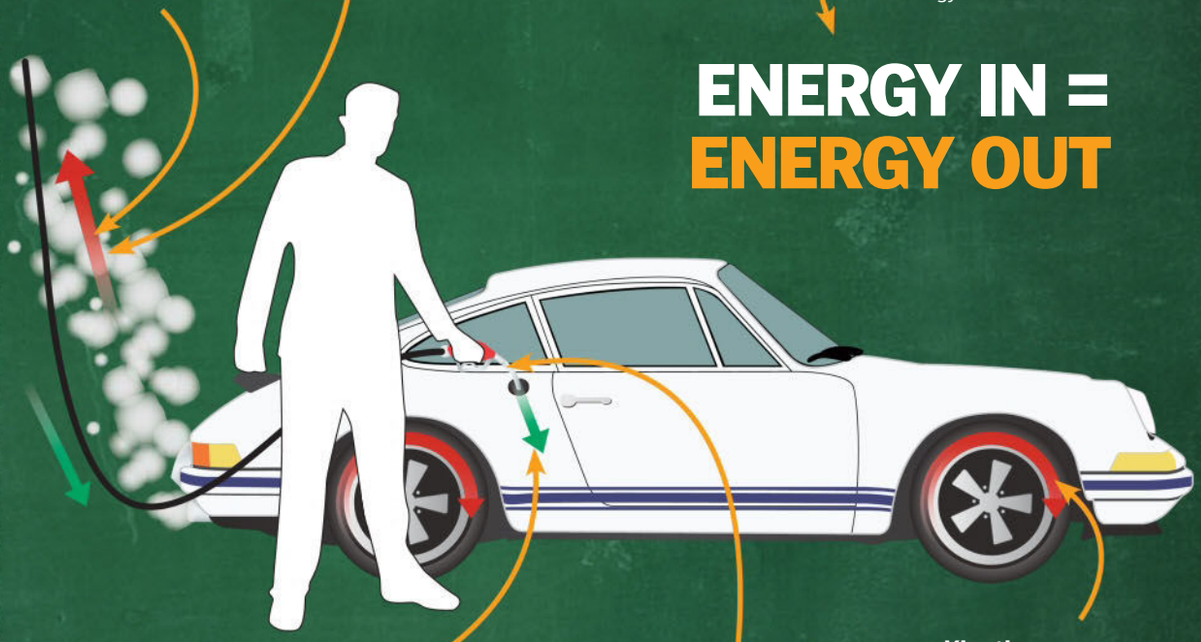
See the laws of thermodynamics in action in this simple example

Heat energy
Some of the fuel's energy is converted into heat energy, which spills out of the car's exhaust.

The second law
Although no energy has been lost, it has become less concentrated as it has spread out into the surroundings.

The first law
The amount of kinetic energy and heat energy created is equal to the amount of energy stored in the fuel.

ENERGY IN = ENERGY OUT



Concentrated energy
Fuels such as gasoline store highly concentrated potential energy in their chemical bonds.

Inefficient system
The less concentrated energy cannot be reused, so when the fuel runs out, the flow of energy stops.

Kinetic energy
In the car's engine, some of the fuel's energy is converted into kinetic energy, which spins the wheels.

THE FOUR LAWS

- **ZEROTH LAW OF THERMODYNAMICS**
  IF TWO OBJECTS WITH THE SAME TEMPERATURE ARE TOUCHING, THERE IS NO NET FLOW OF ENERGY FROM ONE OBJECT TO THE OTHER.
- **FIRST LAW OF THERMODYNAMICS**
  ENERGY CANNOT BE CREATED OR DESTROYED, IT CAN ONLY BE TRANSFORMED.
- **SECOND LAW OF THERMODYNAMICS**
  AS ENERGY TRANSFORMS, IT BECOMES LESS CONCENTRATED AND THEREFORE LESS USEFUL.
- **THIRD LAW OF THERMODYNAMICS**
  IT IS NOT POSSIBLE TO GET THE TEMPERATURE OF A SUBSTANCE DOWN TO ABSOLUTE ZERO (0 DEGREES KELVIN/-273.15°C).

Junk DNA doesn't contain any genes, but it may still play an important role

Junk DNA

Why is there so much rubbish in the human genome?

Genes are the instructions that our cells use to build proteins and other useful molecules. However, less than two per cent of the three billion 'letters' of the human genome contains proper genes. That leaves an overwhelming majority of our DNA code that has no obvious function – so why does it exist?

This is a conundrum that has puzzled scientists since they were first able to read DNA sequences in the 1970s. We have around 20,000 genes, but if the number of genes in a genome is directly proportional to the amount of DNA, then we should actually have around 3 million. But it's not just the lack of genes that's puzzling. Most of the human genome is dull and repetitive, packed full of millions of copies of elements called transposons and other repeated sequences.

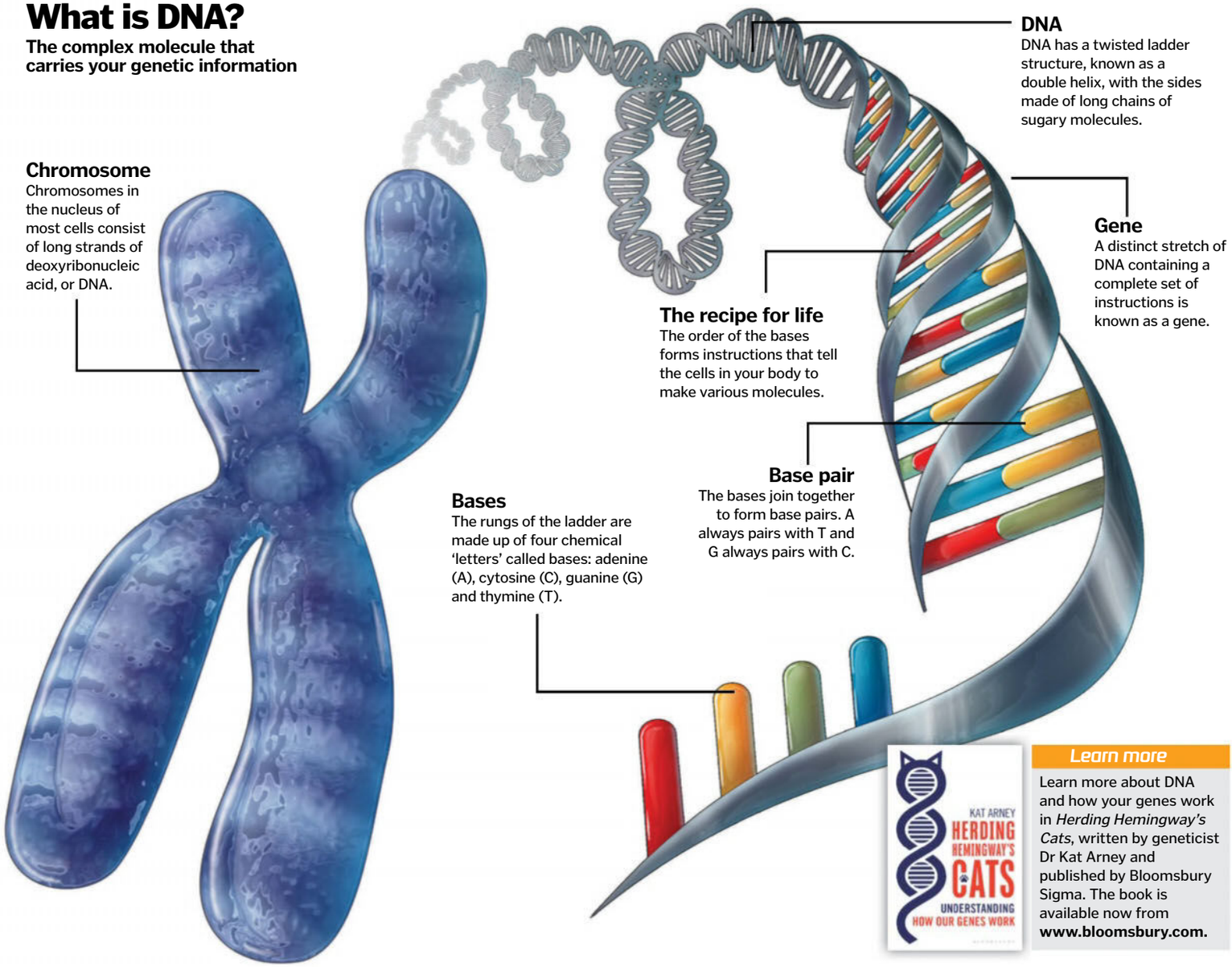
It might be expected that evolution would kick this stuff out, through the process of natural selection. If a stretch of DNA is useful, it sticks around and becomes a permanent part of the genome. But if not... well, it actually sticks around anyway, because evolution is a slow and imperfect process. More recent research also suggests that this 'junk' DNA may not be completely useless.

Some researchers think that our abundance of non-coding DNA is the biological equivalent of bubble wrap, acting as protective packing around our genes and helping to dilute the impact of cancer-causing agents such as X-rays and other carcinogens. It may be that some of the junk is structural, helping to space genes and their control switches out in the right way, although this is hard to prove. Using genetic engineering techniques, researchers can 'glue' a gene right next to the switch that activates it and it still works, suggesting that the precise spacing isn't all that important.

As researchers develop better techniques for probing the functions of stretches of DNA, we'll have a better idea of how much junk we truly have in our biological trunk, and just what it's doing there.

What is DNA?

The complex molecule that carries your genetic information



Learn more

Learn more about DNA and how your genes work in *Herding Hemingway's Cats*, written by geneticist Dr Kat Arney and published by Bloomsbury Sigma. The book is available now from **www.bloomsbury.com.**

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DANIELA ON FACEBOOK

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RYAN ON FACEBOOK

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The future of shopping

From robot shop assistants to virtual fitting rooms, this tech will revolutionise retail

There is no doubt that the internet has changed the way we shop, with many people preferring to click and buy from the comfort of their own homes instead of venturing out to browse the local stores. The convenience of not having to deal with bustling queues or lug your purchases around is no doubt very appealing, but there are huge benefits for the retailers too.

As people peruse their products online, companies can collect lots of useful data about them by way of cookies. These simple text files are downloaded onto your computer when you visit a website and store information about which products you looked at there. The cookies can then be accessed by the retail company, enabling them to target you with adverts based on your preferences, so you will be more likely to take notice. This personalised service often helps to boost sales, but it isn't something the stores on the high street can take advantage of.

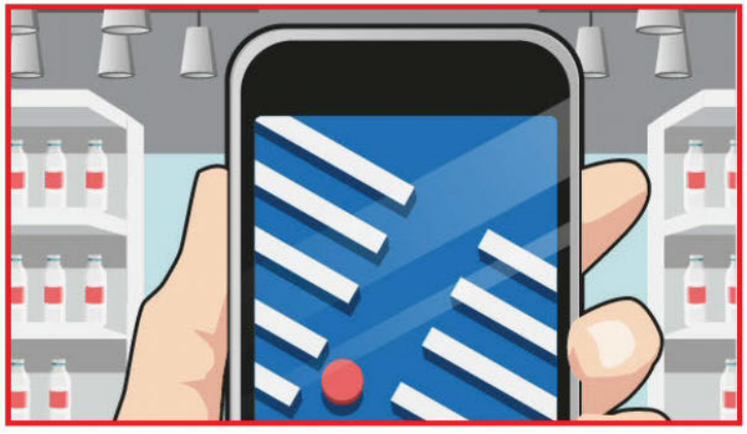
The Dandy Lab is testing interactive information screens and smart footfall counters

With many stores struggling to compete, some clever innovators are developing new technologies that can help them. The Dandy Lab, a menswear and lifestyle outlet in London, is providing a testing ground, enabling companies to try out their ideas on real-life

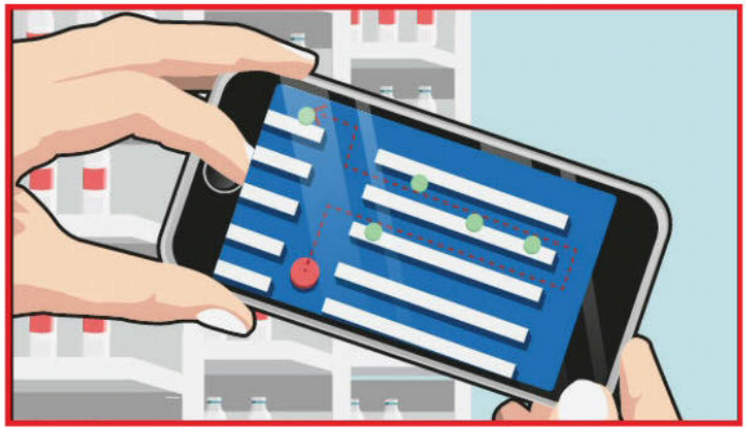
Lighting the way

How Philips' system can help you navigate the aisles

1 Emit the signal
When you enter the store, the light fixture above you emits a unique identification code.



2 Find your location
Your smartphone's camera receives the code telling it exactly where you are in the store.



3 Plan a route
An app on your phone plots the most efficient route to the products on your shopping list.

4 Get the deals
As you walk down an aisle, the lights above send discount codes for the nearby products to your phone.

customers. "At the moment there is a lot of tech for online shops, but there is nothing really happening in the brick and mortar environment," says co-founder Julija Bainiaksina. "We wanted to see how we can integrate technology in-store and make the shopping journey from online to offline seamless and more convenient for the customer."

The 'clothes-store meets retail technology lab' is currently trialling several new methods for enhancing the shopping experience. These include smart mannequins that can send information about the clothes they are wearing to the customers' phones, and a mobile payment app that enables you to use your phone to scan a product's barcode, pay for it and take it home without having to queue at all. The shop is also attempting to replicate online 'cookie' technology with a smart loyalty card scheme that helps shop assistants provide a more personalised service. "We give every single customer a loyalty card containing an RFID [radio-frequency identification] chip, and at the door we have an RFID reader," says Julija. "Once the customer comes back to the shop, we instantly receive information about what they bought, what they like and so on. This gives our sales staff a better understanding of the customer, so they can recommend products based on their previous purchases."

For Julija, using this new technology is not about competing with online retailers but helping online and offline shopping to complement each other. "For physical shops, the main benefit is the ability to showcase their products and provide an experience," she explains. "What we found out is that a lot of people come to the shop just to try on the products, touch them, feel them, and see if they really want them, and then they go home and buy them online. Alternatively, they might do research online, and then come into the shop to try something on and buy it. So both of those channels – online and offline – need to work with each other. The technology should somehow fuse them together to provide one seamless shopping experience for the customer."

In the future, it could be that shops simply become showrooms, stocking tester products for you to try before you purchase them via interactive display screens. Alternatively you may not need to visit the shop at all, instead using a virtual reality helmet to browse and even interact with the products before you part with your cash. In the meantime though, there are plenty of changes already appearing on the high street. From Bluetooth beacons that help you bag a bargain to augmented reality mirrors that let you try on clothes without getting changed; a trip to the mall is about to get a lot more high-tech.

"Smart mannequins can send information about the clothes they are wearing to the customers' phones"

Virtual reality shopping

Imagine being able to wander around a shop and try out the products without ever leaving your house. With several virtual reality headsets now available, this fantasy is fast becoming reality, enabling you to experience the fun of shopping without the stress of crowds or queues. It can also open up some unique try-before-you-buy opportunities. Teaming up with Microsoft Hololens, car manufacturer Volvo was able to create a virtual showroom, allowing customers to strip down holograms of its cars and watch the vehicles in action. Virtual reality production company Visualise has also made it possible for customers of travel agent Thomas Cook to experience holiday destinations before booking a trip.

The growth of virtual reality will enable you to explore shops from the comfort of your home

Volvo's virtual reality showroom lets customers see the inner workings of its cars

Beacon bargains

Everyone loves a bargain, and thanks to a new retail technology, they are becoming easier than ever to find. Devices called beacons are small Bluetooth transmitters that can be installed in shops and communicate with smartphones of passers-by. Already being used on London's Regent Street, the beacons can send exclusive deals to an app on your phone when you walk past a shop, encouraging you to step inside and snap up the offer.

While these beacons can detect when you are nearby, Philips' connected lighting system has taken things even further. The LED lights it has installed along the aisles of a Carrefour supermarket in Lille, France, can work out exactly where you are in the store, and send deals for products in close proximity. The technology is called Visible Light Communication, which uses rapidly flickering LEDs to emit signals that are picked up by your smartphone's camera sensor.

Beacons installed in 'smart mannequins' can tell you exactly what they are wearing

Illustrations by Edward Crooks

The mall of 2020

The high-tech breakthroughs that will change the way you shop

Sensors and trackers

Knowing more about the people who walk into their store can help retailers provide personalised customer service. However, instead of using intrusive facial recognition, Hoxton Analytics has developed a footfall counter that gathers data from people's shoes. A camera records their feet as they walk into the store, and a processor uses clever algorithms to determine their likely age, gender and what brands they like. Other sensors can also track the Wi-Fi pings from customer's smartphones to track where they look in the store.

Information screens

With shops only capable of stocking so many products, some are already including digital displays that let customers access the entire catalogue if they can't find what they want in-store. In the future this could lead to virtual stores, such as the experiment by South Korean store Homeplus. Images of their products were displayed on the walls of a subway station, and by scanning a QR code on their phone commuters could order online and have them delivered by the time they got home.

Virtual fitting rooms

Instead of having to get changed to try on a new outfit, images of the new clothes can be superimposed over live footage of you on the fitting room 'mirror'. The Magic Mirror uses a Kinect body sensor to monitor your position so it can ensure correct placement of the garment on a screen. You can then select a new outfit via gesture or touch screen control, and even take a picture of your new look to send to your friends for approval.

3D printers

As well as selling 3D-printed products, some stores are already letting you print your own. A variety of 3D-printing stores have already started to pop up on the high street and could be a staple of shopping malls in the near future. Customers will be able to download a design or create their own. They can then have the product made while they wait or send their design to the shop and pick up the finished product later.

"3D-printing stores have already started to pop up on the high street"

Smart tags
Tags on your clothes could soon tell you a lot more than the washing instructions. As electronic components have become smaller and cheaper, Norwegian company Thinfilm have been able to develop flexible smart labels with Near Field Communication technology, enabling a wide range of useful information about the product to be sent to your smartphone. This could alert you to ingredients in food items that you might be allergic to, or tell you more about how a product was made.

Digital window displays
Researchers at the Massachusetts Institute of Technology have developed see-through screens that could replace shop windows. Nanoparticles embedded in the material can be tuned to scatter only certain wavelengths of light, letting the rest pass through so the screen appears transparent. This would enable additional product information and adverts to appear over physical window displays – this could then be changed depending on the weather, time of day or even who is walking past the store at the time.

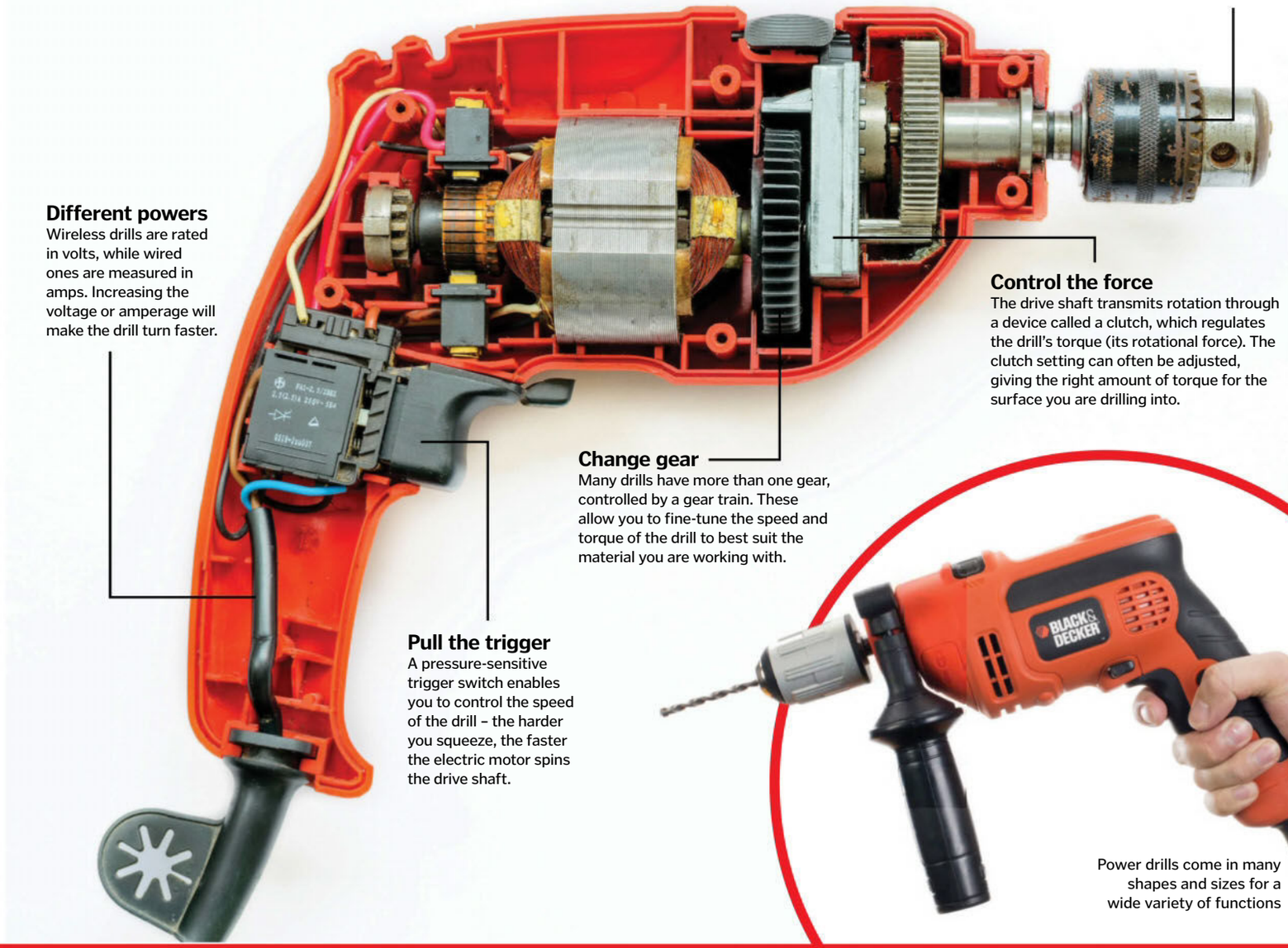
Robot shop assistants
With so many different products in a store, it can be difficult for the staff to know where everything is. This is why researchers at Carnegie Mellon University have developed AndyVision, a robot that can patrol and scan the aisles to create an interactive store map for customers. It can also perform an inventory to alert staff when a product is low in stock or if an item is out of place on the shelves.

Drone deliveries
If you've done your shopping but don't fancy carrying it home or waiting ages for it to be delivered, you could get it sent to your home by a drone. At the moment, delivery drones such as Amazon's Prime Air are only allowed to be flown within sight of the operator, but as computer power improves and sensors become cheaper, automated flying will become much safer. The US Federal Aviation Authority is expected to finalise rules for commercial drone operations later in 2016.

Illustrations by Nicholas Forder

Inside an electric drill

How this toolbox essential powers through your DIY project



Fasten the drill bit
The drill bit attaches at the chuck. Until the 1980s, this needed to be tightened with a special key, but today most drills are keyless and can be secured by hand.

Different powers
Wireless drills are rated in volts, while wired ones are measured in amps. Increasing the voltage or amperage will make the drill turn faster.

Control the force
The drive shaft transmits rotation through a device called a clutch, which regulates the drill's torque (its rotational force). The clutch setting can often be adjusted, giving the right amount of torque for the surface you are drilling into.

Change gear
Many drills have more than one gear, controlled by a gear train. These allow you to fine-tune the speed and torque of the drill to best suit the material you are working with.

Pull the trigger
A pressure-sensitive trigger switch enables you to control the speed of the drill – the harder you squeeze, the faster the electric motor spins the drive shaft.

Power drills come in many shapes and sizes for a wide variety of functions

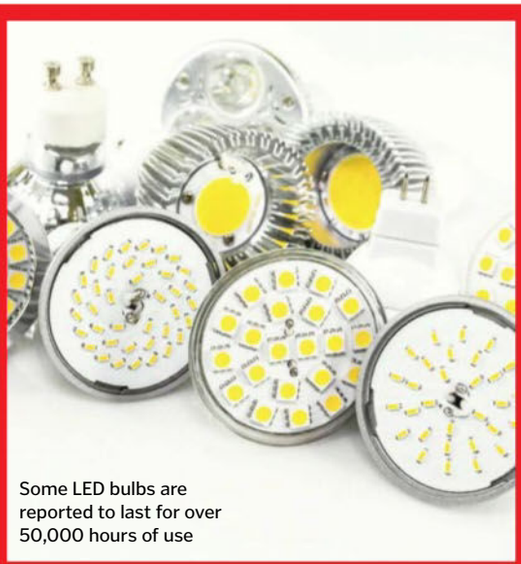
Energy-efficient lighting

What makes LEDs different to traditional bulbs?

Traditional light bulbs – known as incandescent lamps – have illuminated our homes for over 100 years, but now they're on their way out. Inefficient and costly, they work by passing electricity through a small filament, making it incredibly hot. This produces light but a large proportion of the energy is lost as heat. That's why more and more people are choosing to switch to light-emitting diode (LED) lamps. These cost less to run, as they require less electricity, and the bulbs can last up to 25 times longer than conventional ones.

LEDs are semiconductor devices that carry electrical current in one direction. Semiconductors are naturally insulators, but can be turned into conductors by adding atoms of another element, a process called 'doping'. When an electric charge passes through the semiconductor, it activates the flow of electrons across it. This generates energy, which is released as photons – units of light.

LED lamps waste relatively little energy as heat, and as such have the advantage of being much more energy-efficient than their incandescent counterparts.



Some LED bulbs are reported to last for over 50,000 hours of use

How bass guitars work

The secret to those chest-pumping sounds is good vibrations

You might not always be able to hear it, but the bass guitar is one of the most important instruments in modern music. It usually tunes to the same scale as the double bass, but produces sound through an amplifier and a speaker because it lacks any natural amplification of its own.

The key to this electric amplification is a device called a magnetic pick-up. Mounted under the guitar's strings, the pick-up is able to detect their vibrations and send the information electronically to an amplifier and a speaker. In order to do this, the pick-up contains an electromagnet – a magnet wrapped in thousands of turns of fine wire – which can turn the tiny movements of the strings' vibrations into electrical energy. There are many different types of pick-up, and they can be located at various places on the bass guitar's body to give a distinctive combination of sounds.

The electrical signal that comes out of the pick-up would not be audible over the screaming fans, so it needs to be boosted by an amplifier and then driven into a speaker. If the signal is too powerful for the amp, the sound will become distorted in this process, but many musicians use this deliberately to add flair to their playing.

Plucking it apart

Peer inside a bass guitar and discover the origins of its rhythm-driving sound

Tuning up
Bass guitars usually come tuned in the EADG configuration, but that can be changed by tightening or loosening the strings with tuning nuts at the head of the guitar.

Vibrations
A pick-up contains a magnet wrapped thousands of times in fine wire. This coil can 'pick up' vibrations in the guitar string and translate the motion into an electrical signal.

Boost the sound
The signal can be adjusted by dials, and travels from the pick-up, through a power cord and into an amplifier, which massively increases its strength.

Don't fret
By placing fingers over the strings, you effectively shorten their length, and therefore change the vibrations they produce. The further down the neck you play, the higher the resulting notes will be.

Thick strings
Bass guitars work a lot like electric guitars, except their strings are a lot thicker. This means the vibrations are slower, which produces a deeper sound.

Size matters
The shape or depth of a guitar's body can alter the sound it makes – most guitars are solid, but hollow-bodied models can slightly amplify the sound made by the vibrating strings.

Resistance isn't futile

Plucking a bass guitar causes a series of barely-visible vibrations in the string that get passed through an electromagnetic field and amplified by a closed circuit. But that's not the only control you have over the sound you make; even the most basic models of bass have something else to let you produce a range of different effects.

Electric bass guitars come with at least two dials on their body: one for volume and one for tone. The volume dial is typically attached to a 500-kilo-ohm resistor that controls the signal's amplitude: the higher the resistance, the lower the volume. The tone dial (which is also usually a 500-kilo-ohm device) controls which frequencies get cut out – it allows you to make the sound 'sharper' or 'deeper' depending on what passes through it.

Depending on the settings you use for each dial, you can produce incredibly different sounds

How do lenticulars work?

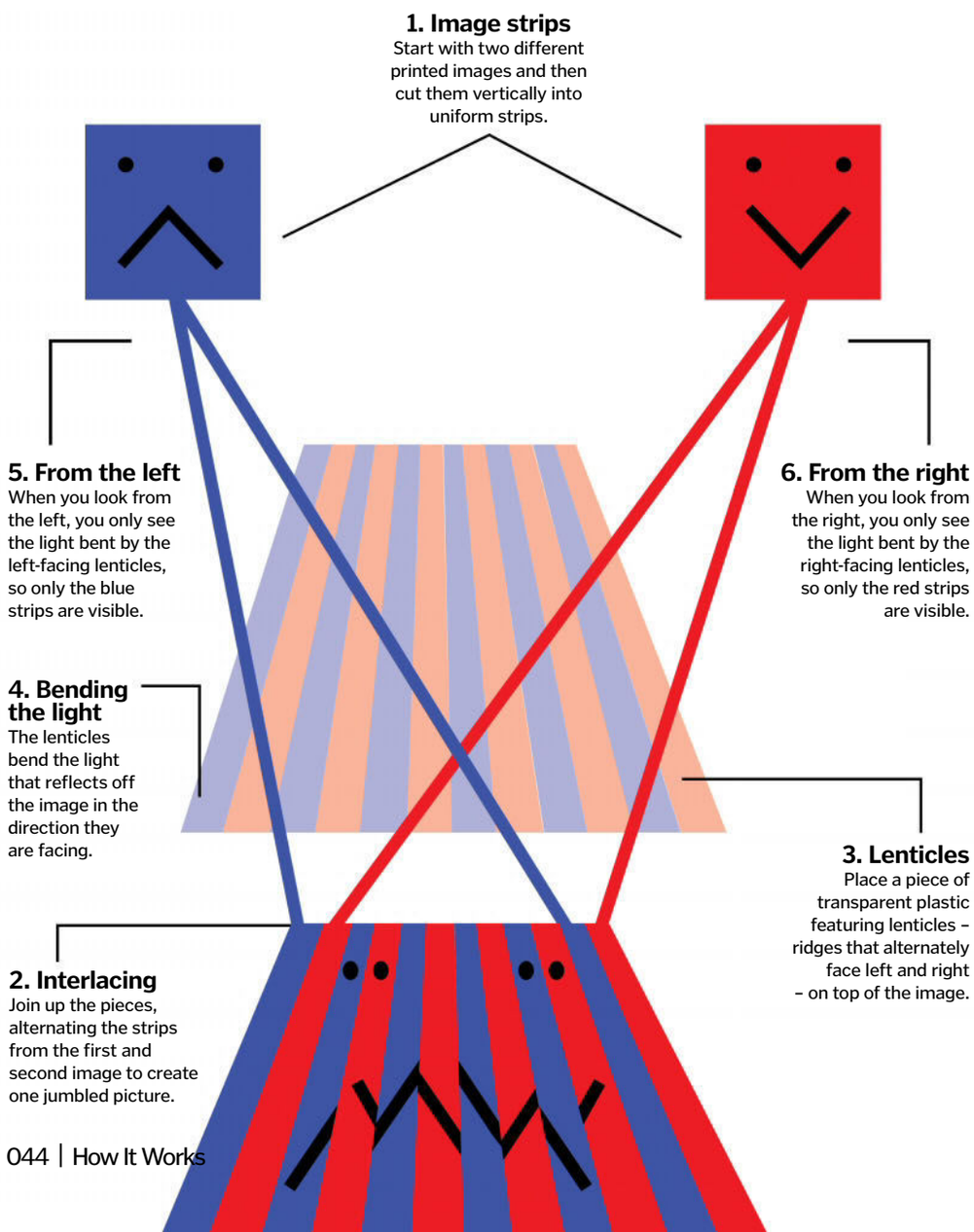
Find out how printed images can change before your very eyes

Popular with printed advertising and magazine covers, lenticulars are pictures that appear to magically change as you look at them from different angles. Essentially they're a very basic form of animation, creating the illusion of movement using a series of static images, a bit like a flipbook. However, instead of flipping pages, you only need to walk past a lenticular image to witness it move.

If you look at them closely, you'll see a piece of ridged, transparent plastic placed over the image. This is used to bend light waves, controlling the direction from which they reach your eye. The ridges in the plastic are lined up perfectly with alternating strips of the jumbled image underneath, and bend the light in alternate directions, such as left and right or up and down. When you look at the image from a certain angle, you only see the sections of the image beneath the ridges that are facing you, but when you or the image moves, a completely different picture becomes visible.

Creating lenticulars

How to make a moving picture



Seabed mining robots

The deep-sea machines that extract valuable minerals from the ocean floor

Spewing hot, chemical-rich fluids from beneath the seafloor, hydrothermal vents are a valuable source of minerals, including copper, nickel, silver and gold. However, as they lie hundreds of metres below the ocean surface, getting at these sought-after deposits is a tricky business. This is why Toronto-based mining company Nautilus Minerals is planning to deploy a team of robots, or Seafloor Production Tools, to do all the hard work for them.

First, the Auxiliary Cutter will carve benches into the seafloor's rough terrain so the other machines have a flat area to work on. The Bulk Cutter will then slice away material from the seabed using spiked rotating drums, leaving it for a Collecting Machine to draw in as seawater slurry. This machine will push the slurry of crushed rock and water through a pipe to the Riser and Lifting System, which will then pump it up to a Production Support Vessel on the surface. Here, the slurry will be filtered to extract the minerals, and the leftover seawater will be pumped back to the seafloor.

From left to right: the Collecting Machine, the Bulk Cutter and the Auxiliary Cutter

The Bulk Cutter robot will use spiked rotating drums to excavate the seafloor

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a gorgeous snow leopard toy

+

an adoption pack

+

regular updates from the field

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Yes, I would like to adopt a snow leopard today

Please indicate how much you would like to give each month

I would like to give ☐ £3 ☐ £5 ☐ £7 ☐ £10

My choice £ ☐ each month (min. £3)

Purchaser details

Title:_____ Initial:_____ Surname: _____

Address:_____

_____ Postcode: _____

Tel no: _____ Date of birth: _____

Email:* _____

*Please supply if you would like to receive emails from WWF (you can unsubscribe at any time)

Gift recipient details (if applicable)

☐ Tick this box if your adoption is a gift, then complete the details of the recipient below

Title:_____ Initial:_____ Surname: _____

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Would you like us to send the adoption pack directly to the recipient? ☐ Yes ☐ No

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DIRECT Debit

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Address:_____

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2. Name(s) of account holder(s)

3. Branch sort code ☐☐-☐☐-☐☐

4. Bank or Building Society account number ☐☐☐☐☐☐☐☐

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6. Instructions to your Bank or Building Society

Please pay WWF- UK Direct Debits from the account detailed on the instruction subject to the safeguards assured by the Direct Debit guarantee. I understand that this instruction may remain with WWF-UK and, if so, details will be passed electronically to my Bank/Building Society. Banks and Building Societies may not accept Direct Debit Instruction for some types of account.

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Elon Musk hopes to make reusable rockets the future of space travel

Elon Musk

How this South African dreamer revolutionised the world

In 1981, at the age of ten, a young South African boy with a passion for computers was told by his father that they were "toys that will amount to nothing". Undeterred, he bought his own computer, developed a video game, and sold it for $500.

Three decades later and that same boy is now a multi-billionaire, the CEO and founder of several wildly successful companies that have revolutionised everything from space travel to solar power to – of course – computers. Despite his humble beginnings, Elon Musk is now one of the most important thinkers and innovators of our time.

Many have watched Musk's meteoric rise with awe, especially considering he is still just 44 years old. The journey began at the age of 17 when Musk left his home in Pretoria, South Africa and moved to Canada where he went on to study at Queen's University in Ontario until 1992, followed by the University of Pennsylvania in Philadelphia. It was here that his highly ambitious nature began to manifest itself.

"He is perhaps best known for Space X, but another of his companies, Tesla Motors, regularly makes the headlines"

"When I was in college, I decided that the three areas I would like to work on were the internet, space exploration and clean energy," Musk said in an interview with the Institute of Physics in 2007. And he delivered on his promise. The first, the internet, was his big breakthrough. He founded two companies, Zip2 and PayPal (originally known as X.com), the first an online publishing software and the second a well-known online payment service. Zip2 was sold for more than $300 million in 1999, and PayPal for $1.5 billion in 2002, earning Musk his early fortune in Silicon Valley.

From there, he set his targets on space. In 2002, he founded the Space Exploration Technologies

A LIFE'S WORK

How one man's innovation has influenced the world of tech as we know it

1971
Elon Musk was born on 28 June 1971 in Pretoria, South Africa.

1981
Musk starts developing his first piece of software, a video game called Blastar. He later sells it for $500.

1989
Musk leaves South Africa and moves to Canada. He then studies for his physics degree at Queen's University in Ontario.

1995
He moves to Silicon Valley to start online publishing company Zip2, which he later sells to Compaq for $307 million.

1999
X.com, an online payment service, is founded by Musk. Later called PayPal, it is sold to eBay for $1.5bn in 2002.

The headquarters of PayPal are based in California

The big idea

Making rockets reusable is one of Musk's biggest goals

The entrepreneur has often likened rocket travel to discarding an airplane after every flight, as up until now all rockets were discarded after launch. So his SpaceX company is developing reusable rocket technology that could return to the ground after launch. This is achieved using aerodynamic 'fins' and by reigniting the thruster on the rocket. Following a handful of failures, SpaceX achieved this on 22 December 2015, landing the first stage of a Falcon 9 rocket at Cape Canaveral, Florida.

This was the moment the first stage of the Falcon 9 touched down

Corporation, better known as SpaceX, with the goal being to massively reduce the cost of getting to space and, eventually, land humans on Mars. They were certainly ambitious goals, and ones that were met with heavy scepticism at the start – especially considering how many other private space companies had tried and failed. But Musk was determined.

By 2008, SpaceX had launched its first rocket – the Falcon 1 – into orbit. In 2010, it became the first private company to launch and return a spacecraft – the Dragon – atop its new Falcon 9 launch vehicle. In 2012, Dragon became the first private capsule to dock with the International Space Station (ISS). And recently, on 22 December 2015, SpaceX became the first company – private or otherwise – to safely return the first stage of an orbital rocket to the ground. This reusability aspect will be a key goal in bringing down the cost of launching.

Musk has forever changed the playing field in space exploration. He is perhaps best known for SpaceX, but another of his companies, Tesla Motors, regularly makes the headlines, and was Musk's first foray into the clean energy market.

He became part of this electric car company in 2004, and others sat up and took note when it launched the first fully electric sports car in 2008. Tesla has now almost single-handedly changed the automotive market with a series of electric cars – the Roadster and Model S, X and 3 – and big things are expected of the company in the future.

With good reason, the world's eyes have been trained on Musk these last few years. He has transformed the three areas that he set his sights on – and from a small South African boy with a passion for computers, Musk is now one of the most revered thinkers in the world. We will wait to see what he does next with bated breath.

Musk wants to land humans on Mars in the next few decades

Tesla has shaken up the automobile market

Five things to know about... Elon Musk

1 Iron Man
Jon Favreau, the director of the *Iron Man* films, reportedly decided to use some of Musk's characteristics in the character of Tony Stark, owing to the similarities between the real and fictional billionaires.

2 Work, work, work
Musk is a self-professed workaholic. With so many companies to run, he works up to 100 hours per week, which has caused some notable and high-profile marital disputes.

3 Hyperloop
One of Musk's more recent ideas is a transportation system that will be able to carry passengers in pods through vacuum tubes at speeds of up to 1,220km/h.

4 Life on Mars
In a recent biography written by journalist Ashlee Vance, Musk revealed that he hopes to have an 80,000-strong Martian colony up and running by 2040.

5 SolarCity
Musk has another somewhat lesser-known company, SolarCity, which is the largest solar power provider in America. It is run by his cousin, Lyndon Rive.

2002
Musk founds SpaceX, with the goal of dramatically reducing the cost of space travel and ultimately transporting humans to Mars.

2004
Musk joins the board of the electric car company, Tesla Motors.

2008
Tesla launches the world's first electric sports car, the Tesla Roadster, the same year Musk becomes CEO.

The Tesla Roadster was a game-changer when it entered the market

2012
SpaceX becomes the first private company to dock a vehicle – the Dragon – with the ISS.

Dragon is the operational cargo spacecraft that can return from space

2014
NASA awards Musk's SpaceX a contract to start taking astronauts to the ISS by 2017.

The inner workings of an iron

Discover the clever technology that keeps your clothes crease-free

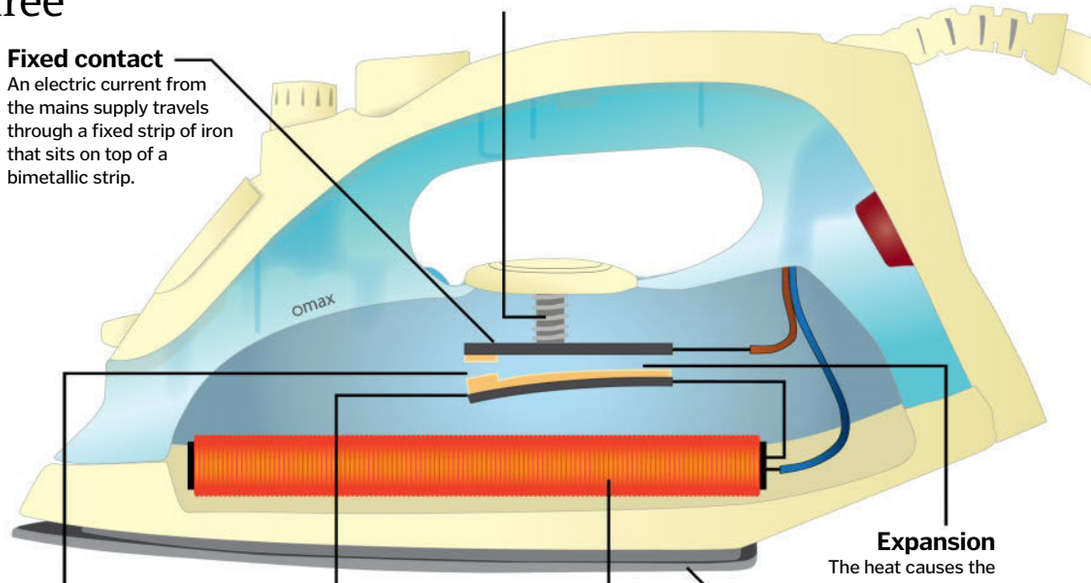
When a hot iron glides over creased clothes, the heat weakens the molecular bonds in the fabric's fibres. This means they can move into new positions so that you can smooth them out before the fabric cools and locks these new bonds into place.

The temperature of an iron is controlled by a thermostat. This consists of a bimetallic strip – two different metals fitted close to the heating element. As they are heated, the metals expand by different amounts, bending into a curve. The current flows through the bimetallic strip to the heating element, which turns electricity into heat and warms up the base of the iron (known as the sole plate). When the thermostat reaches the desired temperature, the components of the strip will curve enough to pull away from each other and break the circuit. This mechanism also prevents the iron from overheating.

As well as using heat to smooth out creases, some irons also use steam. Water from an internal tank is released into the hot sole plate where it instantly vaporises. The resulting water vapour is released through holes in the plate, which helps to remove wrinkles.

Iron engineering

How do irons give off just the right amount of heat?



Thermostat screw
The position of the fixed contact can be adjusted to control the temperature at which it disconnects from the bimetallic strip.

Fixed contact
An electric current from the mains supply travels through a fixed strip of iron that sits on top of a bimetallic strip.

Expansion
The heat causes the brass in the bimetallic strip to expand, more so than the iron.

Bending
The expanding brass causes the bimetallic strip to bend until it eventually disconnects from the fixed contact and breaks the circuit, preventing the iron from overheating.

Bimetallic strip
Consisting of strips of iron and brass, this stays flat when cool, connecting with the fixed contact to complete the circuit.

Heating element
The current is passed from the bimetallic strip to a heating element, which converts the electricity into heat.

Sole plate
The heating element heats up the sole plate through conduction, allowing it to transfer the heat to your clothes.

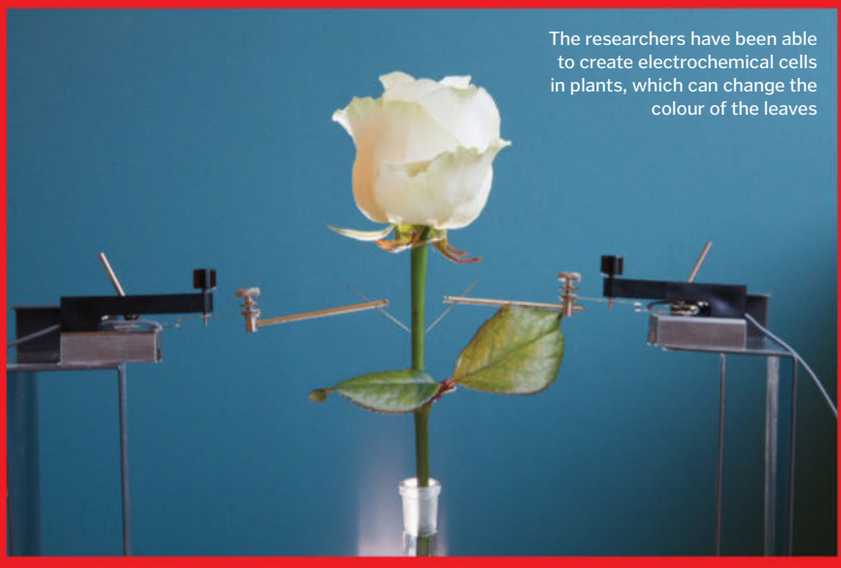
THE WORLD'S FIRST CYBORG PLANT

How to turn a living rose into an electric circuit

If you struggle to keep your houseplants alive, then the idea of a shrub that can alert you when it needs watering would certainly be appealing. Thanks to researchers in Sweden, that idea is much closer to becoming reality.

The team from Linköping University has created the very first electronic plant, which they say opens up the possibility of being able to read and regulate plant growth by measuring the concentration of their various molecules, as well as making use of the energy they produce through photosynthesis in a fuel cell.

To create their cyborg rose bush, the researchers used a synthetic polymer called PEDOT-S, which was drawn up through the plant's stem by capillary action – the same process plants use to absorb water. Once inside this channel, the polymer converted itself into a thin film that could conduct electrical signals, but still left enough room for water and nutrients to pass through and keep the plant alive. By placing an electrode at each end of the conductive film, the team was then able to create a transistor: an electronic switch that completed the circuit.



The researchers have been able to create electrochemical cells in plants, which can change the colour of the leaves

How do multicopters take off?

The science and tech that gets commercial drones into the air

Drones, also known as unmanned aerial vehicles or UAVs, come in all shapes and sizes, from the mammoth machines used by the military, to the toys you fly in your back garden. However, while they are all operated remotely, the methods they use to get into the air can differ greatly.

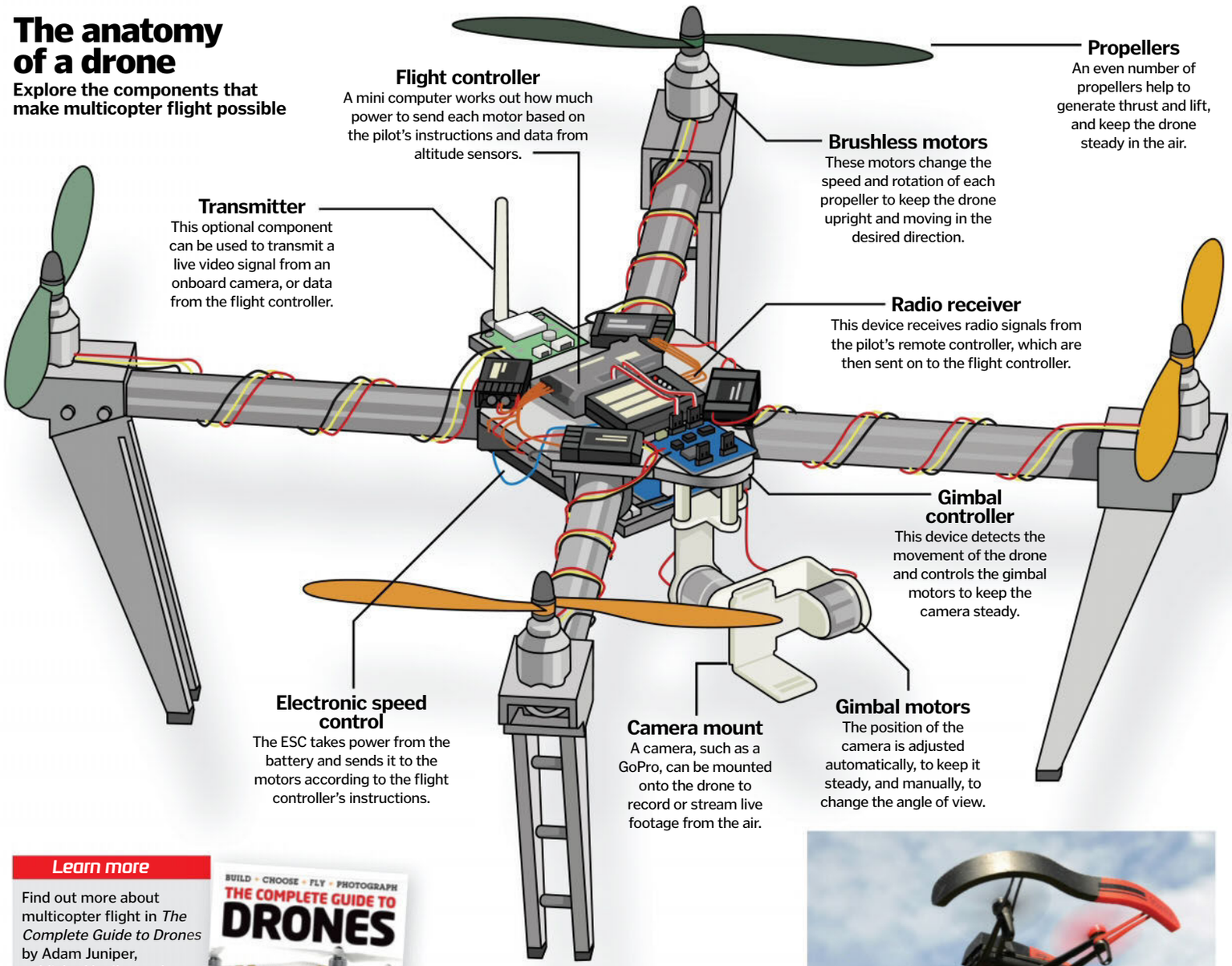
Those that take off like normal airplanes use engines or vertical propellers to create thrust, propelling them forwards and causing air to flow rapidly over the wings. The curved shape of the wings then deflect air, creating a difference in pressure above and below. As the air pressure below the wing is higher, this generates lift to push the drone upwards.

VTOL (Vertical Take Off and Landing) drones however, don't need a runway for take-off. They use engines or horizontal propellers to direct thrust downwards, thereby creating lift that gets them off the ground. This is the method favoured by commercial drones, which often come in the form of multicopters.

These miniature flying machines feature four or more horizontal propellers, which create plenty of thrust to allow them to hover above the ground. The propellers rotate in opposing directions to avoid spinning the multicopter out of control. They can also be used to change its direction by increasing or decreasing the speed at which certain propellers rotate. For example, by causing the propellers on the left side to spin faster, they generate more lift on that side and cause the drone to lean to the right.

The anatomy of a drone

Explore the components that make multicopter flight possible



Propellers
An even number of propellers help to generate thrust and lift, and keep the drone steady in the air.

Flight controller
A mini computer works out how much power to send each motor based on the pilot's instructions and data from altitude sensors.

Brushless motors
These motors change the speed and rotation of each propeller to keep the drone upright and moving in the desired direction.

Transmitter
This optional component can be used to transmit a live video signal from an onboard camera, or data from the flight controller.

Radio receiver
This device receives radio signals from the pilot's remote controller, which are then sent on to the flight controller.

Gimbal controller
This device detects the movement of the drone and controls the gimbal motors to keep the camera steady.

Electronic speed control
The ESC takes power from the battery and sends it to the motors according to the flight controller's instructions.

Camera mount
A camera, such as a GoPro, can be mounted onto the drone to record or stream live footage from the air.

Gimbal motors
The position of the camera is adjusted automatically, to keep it steady, and manually, to change the angle of view.

Learn more

Find out more about multicopter flight in *The Complete Guide to Drones* by Adam Juniper, published by Ilex and available now for £14.99 ($19.95). The book also gives piloting tips and advice for building your own drone.

Multicopters typically have an even numbers of propellers; quadcopters have four

Evolution of... Tablet computers

From PalmPilots to iPads, discover how the tablet tapped into our lives

Before Steve Jobs introduced the world to the iPad, tablets were chunky, slow devices that weren't particularly intuitive. Rather than tapping an on-screen keyboard, you had to write notes on the touchscreen with a stylus, which were then converted into text by handwriting recognition software. Apple's first mobile computing device, the Newton MessagePad, was ridiculed because of flaws in this software, as it regularly got words completely wrong. Microsoft's first tablet wasn't much better, as it was simply Windows XP desktop software crammed onto a smaller device and still needed to be used with a stylus.

It would be another eight years before Apple finally gave the people what they wanted. The iPad was a complete reinvention of the tablet computer, featuring a tailored operating system and full touchscreen capability in a thin, lightweight device. Its brain is a microprocessor, smaller than those found in full-sized computers, so it does not generate as much heat or require a bulky fan to keep it cool. Accelerometers and gyroscopes help it work out its orientation, so the display will always appear the right way up, and the screen features Multi-Touch technology to recognise when you 'pinch to zoom' with two fingers.

Today, tablets are available in all sorts of shapes and sizes, and the latest trend seems to be the bigger the better. Microsoft's Surface Pro and Apple's iPad Pro balance both size and power to provide the functionality of a laptop with the convenience of a tablet, and could soon spell the end for the PC as we know it.

Inside the iPad Pro

Delve into the inner workings of Apple's new supersized tablet

Speakers
With a speaker in each corner, the Pro recognises which way up it is to ensure the top two speakers deliver higher frequency sound.

Smart Connector port
Apple's Smart Keyboard can connect to the Pro via magnetic contacts, which relay power and data between the devices.

Battery
The 38.5-watt-hour rechargeable lithium-polymer battery offers up to ten hours of use on a single charge.

A brief history of the tablet

The successes and failures that shaped the modern tablet computer

1968 Dynabook

The idea of the tablet computer was first dreamt up by Alan Kay, a computer scientist for Xerox. He envisioned the 'Dynabook' as a portable educational device for children, but it was never actually made.

1989 GRiDPad

Created by Palm Computing founder Jeff Hawkins, the GRiDPad had a ten-inch screen with stylus input and handwriting recognition. However, its hefty price tag restricted it to use by law enforcement and the military.

1993 Apple Newton MessagePad

With John Sculley as CEO, Apple released the first Personal Digital Assistant (PDA) device. It could run a few apps and featured handwriting recognition, but wasn't very good at it.

1996 PalmPilot

Palm Computing's affordable PalmPilot made the PDA truly popular. Early models featured monochrome touchscreens and cable syncing, but later versions were kitted out with colour displays and wireless data access.

2002 Microsoft Tablet PC

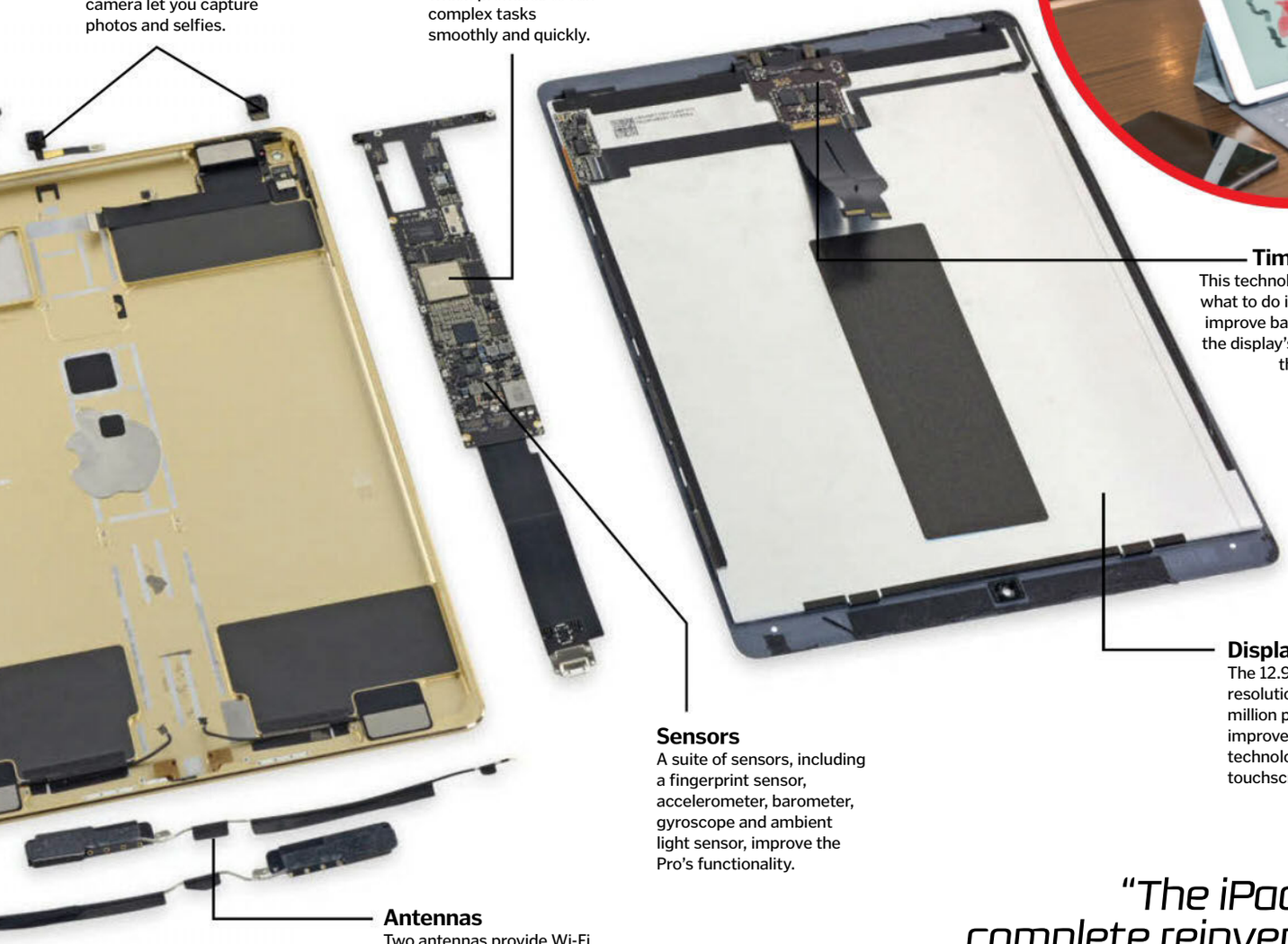
Bill Gates unveiled a prototype tablet in 2000, and devices running Windows XP Tablet PC edition went on sale two years later. However, the weighty devices were not a success.

DID YOU KNOW? *300,000 iPads were sold on launch day in 2010, and around 3 million have been bought since then*


The 12.9-inch iPad Pro can be used with a Smart Keyboard and the Apple Pencil

Cameras
The 8-megapixel rear-facing iSight camera and 1.2-megapixel front-facing FaceTime HD camera let you capture photos and selfies.

Processor
On the Pro's logic board is the all-new A9X chip, which promises to run complex tasks smoothly and quickly.



Timing controller
This technology tells each pixel what to do individually and can improve battery life by cutting the display's refresh rate when the content is static.

Display
The 12.9-inch high-resolution display has 5.6 million pixels and features improved Multi-Touch technology for enhanced touchscreen sensitivity.

Sensors
A suite of sensors, including a fingerprint sensor, accelerometer, barometer, gyroscope and ambient light sensor, improve the Pro's functionality.

Antennas
Two antennas provide Wi-Fi speeds of up to 866 Mbps and 4G LTE mobile internet speeds of up to 150 Mbps.

"The iPad was a complete reinvention of the tablet computer"

2005
Nokia internet tablets
A series of devices that were a cross between PDAs and mobile PCs were released by Nokia up to 2012. They were intended for web browsing and email, but also served as portable media players.

2007
Amazon Kindle
Amazon snuck onto the scene in 2007 with the Kindle. The e-reader could only be used for books, but its design was a tantalising glimpse of what was to come.

2010
Apple iPad
Steve Jobs unveiled the first iPad three years after the launch of the iPhone. Its 9.7-inch touchscreen and extensive app library redefined the tablet PC, and Apple's competitors soon flooded the market with Android-enabled rivals.

2012
Microsoft Surface
Microsoft returned to the tablet game with its iPad competitor, the Surface. With a kickstand and detachable keyboard, it was intended to replace the laptop instead of accompany it.

2015
Apple iPad Pro
With smartphones becoming tablet-sized, tablets had to grow too, and so a series of supersized devices entered the market. When Microsoft released the Surface Pro, Apple quickly followed with the iPad Pro, their biggest tablet yet.

Pet trackers

How these wearable devices can keep tabs on your furry friends

Right now, there are 31 satellites circling Earth in what is known as the Global Positioning System (GPS) Constellation, feeding back information to millions of GPS devices. Whether you're searching for nearby car parks on your sat nav or tracking down a lost pet, the technology works in the same way.

A GPS receiver in your pet tracker locates at least three of these satellites to calculate exactly where on the planet it is. To do this, the receiver intercepts signals from the satellites and calculates how long it took them to arrive. Because the signals always travel at the speed of light, it is possible to work out the distances between each of the satellites and your furry friend.

The exact position of the receiver can be pinpointed via a process called trilateration. Say your pet's tracker receives signals from three satellites. It can calculate how far away each satellite is, but not which direction the individual signals came from. For example, if one signal is calculated to come from 20,000 kilometres away, the receiver could lie anywhere on an imaginary sphere with a 20,000-kilometre radius surrounding that particular satellite. This is why multiple satellites are required in GPS; finding where three or more of these spheres from different satellites intersect enables the receiver to figure out exactly where your pet is. The more satellite signals the tracker can pick up, the more accurate the position will be.

As apps and tech become more complex, GPS receivers are able to store more detailed maps on the devices. So, if your pet is wearing a tracking device, you will be able to locate specific streets, fields or buildings that it walks past, using GPS.

We thought our cat was a lazy old mog, but her GPS tracker shows she is pretty active

Chips in their shoulder

Microchips are always active and require no effort to maintain

Before GPS became more accessible, microchips were the best way of locating missing animals. A microchip is no bigger than a single grain of rice and is surgically implanted under the animal's skin.

It contains two things: a registration number, and the phone number of the person registering the animal. Should the pet become lost, a handheld scanner can read the radio frequency of the chip, and the vet or animal shelter are then able to get in touch with the pet's owner.

These chips don't use GPS technology, but rather are based on radio-frequency identification (RFID) technology. This consists of a small chip and an antenna that provides a unique identifier for an object, such as a barcode.

Although they are less high-tech than GPS, microchips have several advantages; they don't require a power source, there are no moving parts and a single chip will last your pet's entire lifetime (something that can't be said of a GPS tracker).

How GPS works

The hardware in the sky explained

1 The satellite network
Each of the satellites orbiting Earth at an altitude of 20,000km broadcasts its position and time at regular intervals.

2 Working it out
Each satellite completes a full orbit of the Earth every 12 hours, broadcasting a constant synchronised time signal from an onboard atomic clock.

3 The GPS receiver
The data broadcast by three or more satellites travels at the speed of light and is picked up by the GPS receiver, which calculates how far away each satellite is.

4 Sending the data
Data can be taken and stored by a GPS unit at frequent intervals and sent to a data network, making a map of your pet's movements.

5 Trilateration
By calculating how far away your pet is from multiple satellites, the GPS tracker can accurately pinpoint its position.

6 Interpreting the location
Using the satellite position results and accurate map data, the tracker can let you know exactly where your pet is.

From the makers of HOW IT WORKS

CAN A COW JUMP?

How much does the sky weigh? How do fish sleep? Why do boomerangs come back? These are just a few of the crazy questions asked and answered in Can A Cow Jump? Dive into the science behind each and expand your knowledge!

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NATURAL BORN KILLERS

Revealed: The deadly tactics of the world's greatest hunters

Whether it's a lion taking down a wildebeest, or a spider devouring a wasp, the predator–prey relationship is a constant carousel of eat or be eaten. It's survival of the fittest. Unfortunately, it's very often the little guy that pays the price for the never-ending march of life. That's because Mother Nature has gifted many of the predators of the animal kingdom with incredible adaptations to lighten the load and simplify their task, no matter how high up they are in the food chain.

There's no stronger hunting force than that of a pack. It has the benefit of teamwork, the use of varied skills, as well as safety in numbers. The drawback for animals hunting in groups is that there has to be enough food to go around, but that's remedied by the fact that many hands, or paws, make light work.

Wolves are a key example of pack hunters, where the relationships between the animals are so intricate that they are able to communicate effectively and work as one ruthless unit. Each individual animal will have a specific role to play, often based on age, gender and social standing.

A similar structure applies to many other animals. For example, an African community of chimps have been hunting together so efficiently that they have decimated the population of their prey, the red colobus monkey. Dolphins, too, will maximise their prey intake by working together to trap fish. Living in close familial units, dolphins communicate in a conversation of complex clicks and whistles for efficient fishing.

Dolphins' cetacean cousins, killer whales, also employ this technique. These highly intelligent ocean giants have been frequently witnessed swimming in formation to create a giant bow wave, washing the seals perched atop ice floats into their waiting jaws. Killer whales have been known to spend hours and hours chasing down their prey, relying on their stamina to keep up the pursuit until their prey tires.

This type of persistence hunting is employed by many other group predators as well as lone rangers, usually those with athletic builds and ravenous appetites. Wolves and wild dogs use the combined strength of the pack to pursue the prey until they collapse with exhaustion.

A successful predator is not a fussy eater; take the hyena, for example. These animals are known for being first-class scavengers, able to sniff out carrion from over four kilometres away, but they're also skilled hunters. Prone to marauding in pairs, one hyena will distract a mother

"Wolves are able to communicate effectively and work as one ruthless unit"

Hunting with the wolf pack

Strength and wit are used to take down prey

1 When the pack is on the prowl, they're searching for signs of food and assessing favourable factors such as the weather and terrain.

2 Once the prey is spotted, the pack approaches. They may herd the prey into a more advantageous area, or track them to cause panic and fatigue.

3 When the prey (often a herd of deer, or other hoofed animals) is panicked and running, the wolves will come in from different sides to lunge at the group.

4 Smaller and slower individuals of the herd, such as the very young, weak or elderly are the easiest for the individual wolves to pick off.

5 Once a wolf has taken down a victim, the chase will stop. The wolves will bite to restrain and dispatch the prey before tucking in.

wildebeest and the other will move in for the calf. In larger groups, it's possible to take down even larger animals for a more profitable kill. Hyena too use the endurance hunting method; they can sprint at 60 kilometres per hour, and can sustain a speed of 40 to 50 kilometres per hour over a distance of five kilometres, snapping at the hooves of their quarry until the panicked beast gives up the ghost.

Lone hunters don't have the combined strength of a pack or a pod to rely on, and so will often have some amazing adaptations to help them in their quest for nutrition. One such critter is the red fox. These brush-tailed foragers pick up low frequency sounds and are able to hear small rodents as they scamper under nearly a metre snow. Without even seeing the target, a fox can launch an accurate pounce, leap into the air and then land to pin its prey down. Scientists believe that foxes actually align themselves with Earth's magnetic field to pinpoint the exact location of their prey, preferring a northeasterly attack for an incredible 73 per cent success rate.

Red foxes use the Earth's magnetic field to line up an accurate pounce on prey

Snakes also use super senses to hunt. They detect a cocktail of visual and chemosensory cues to track down a suitable victim, and are also capable of seeing endothermic heat signatures. Once they have singled out a tasty morsel, constrictor species will deploy the death squeeze. Studies have shown that snakes can match the strength and duration of the constriction to the heartbeat of their prey, making for a scarily efficient dispatch.

Burly brown bears, on the other hand, have the advantage of being at the very top of the food chain. They are solitary and omnivorous and will nibble on nuts and berries or use their sheer bulk to take down deer and even moose.

Yet for many lone hunters, the element of surprise is crucial for success, and that is where the ambush hunter thrives. Setting traps and lying in wait is a very energy-efficient way of hunting. On land, one of the largest ambush hunters is the tiger, which relies on its rich camouflage of stripes for concealment until the opportune moment to strike. Tigers are also excellent swimmers and have been known to attack from the water.

As well as camouflage, the use of tools to hide in plain sight is a feat of magnificence in the animal kingdom. Devious species of both crocodiles and alligators are known to place twigs and sticks across their noses, then lie in wait for unsuspecting birds. Thinking that they're plucking up some prime nesting material from the water, the bird is then quickly snapped up – the first ever evidence of tool usage in reptiles.

BEARS AND THE SALMON RUN

How brown bears fish out the tastiest mouthful

"A predator's environment can govern how it interacts with its prey"

Learning the ropes
Cubs will learn to hunt by watching their mothers from the bank. In adulthood, bears will mostly use the primary fishing method employed by their mothers.

Sit and wait
The bear sits in the water, focusing on the spot in front of him. When a salmon swims into view, he pins it to the streambed.

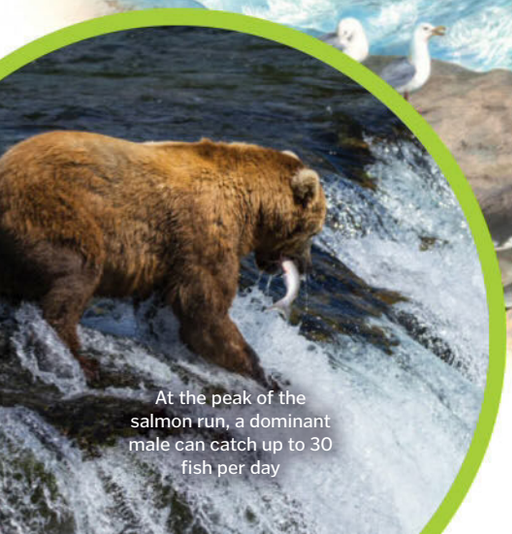
Smash and grab
When the salmon run is in full flow, bears will stand in the stream and hook out nearby fish using their long, sharp claws and giant, paddle-like paws.

Dinner is served
Once a salmon is safely landed, the bear will take it off to a secluded spot. It typically eats just a quarter of the fish: the fatty and delicious parts.

Beware of pirates
'Pirating' refers to sneak-thief bears that simply wait for others to do all the hard work. It's not a common behaviour, but daylight salmon robbery does happen occasionally.

Fishing at the falls
The bear takes its position at the top of a small waterfall and simply waits for salmon to leap up the falls into its waiting jaws!

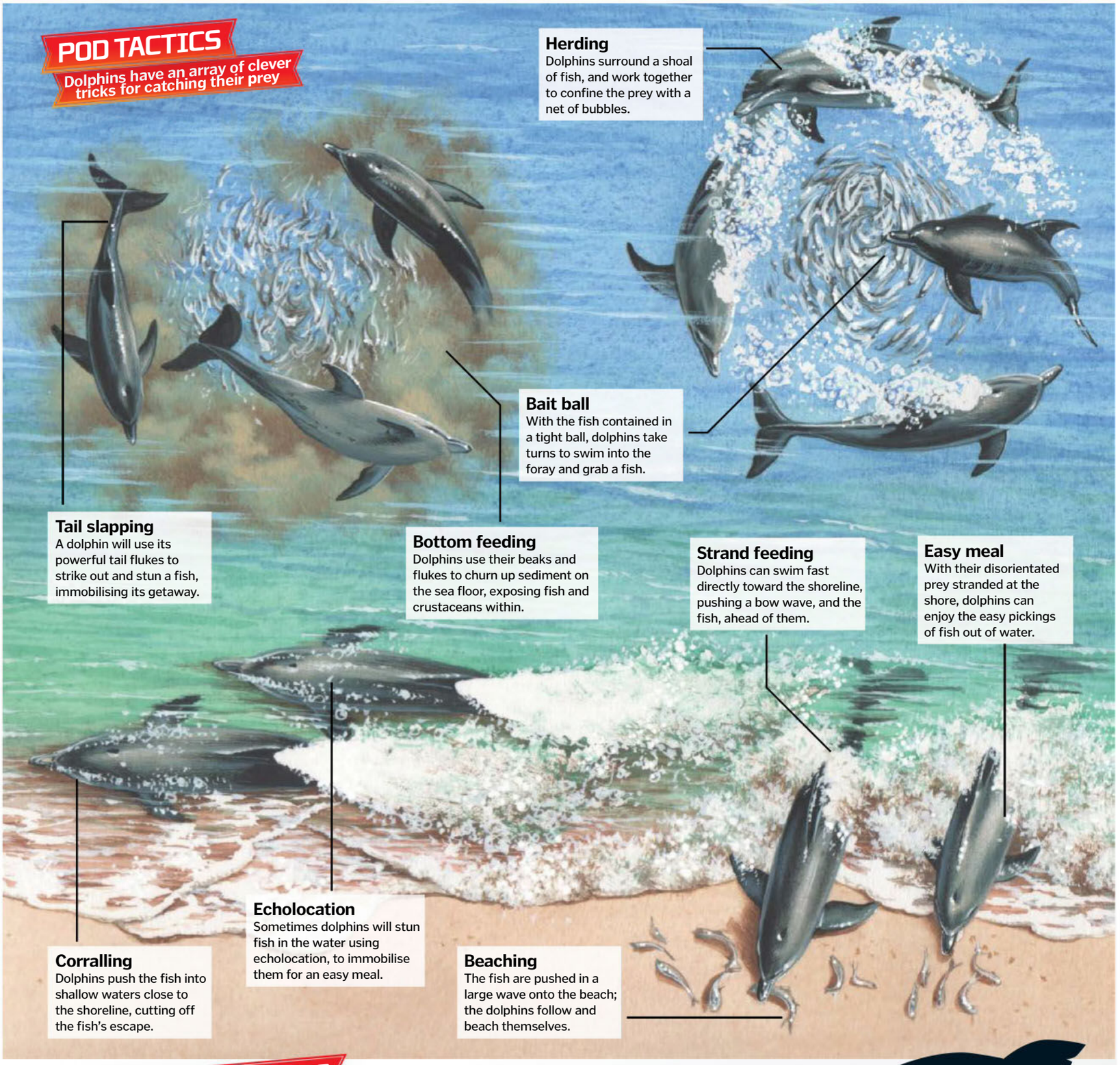
Defending the spot
The best fishing spots are generally occupied by the most dominant bears in the area, and are defended fiercely from encroaching competition.



At the peak of the salmon run, a dominant male can catch up to 30 fish per day

POD TACTICS

Dolphins have an array of clever tricks for catching their prey



Herding
Dolphins surround a shoal of fish, and work together to confine the prey with a net of bubbles.

Bait ball
With the fish contained in a tight ball, dolphins take turns to swim into the foray and grab a fish.

Tail slapping
A dolphin will use its powerful tail flukes to strike out and stun a fish, immobilising its getaway.

Bottom feeding
Dolphins use their beaks and flukes to churn up sediment on the sea floor, exposing fish and crustaceans within.

Strand feeding
Dolphins can swim fast directly toward the shoreline, pushing a bow wave, and the fish, ahead of them.

Easy meal
With their disorientated prey stranded at the shore, dolphins can enjoy the easy pickings of fish out of water.

Echolocation
Sometimes dolphins will stun fish in the water using echolocation, to immobilise them for an easy meal.

Corralling
Dolphins push the fish into shallow waters close to the shoreline, cutting off the fish's escape.

Beaching
The fish are pushed in a large wave onto the beach; the dolphins follow and beach themselves.

PREDATOR STATISTICS

The rate of hunting success can vary. Polar bears only have a ten per cent success rate, but just one 55-kilogram seal has enough blubber and energy to sustain a bear for around eight days. Here are some more killer statistics to show just how hard predators have to work to survive.

UNDER 30 MINS
The time it takes for a hyena pack to devour a whole zebra, bones and all

95%
The dragonfly's success rate; it singles out, catches and eats each individual fly

5,000 ITEMS OF PREY
The amount a breeding pair of barn owls catches in a year, for themselves and their owlets

48%
The number of successful surface attacks on seals launched by great white sharks

The predatory sleuth of the marine world is the octopus. Hunting crabs and crustaceans, these cephalopods are able to disguise both their colour and texture to avoid detection. Once close enough to its victim, the octopus will then swoop down to envelop the morsel in its arms, delivering a bite laced with a potent neurotoxin capable of turning crab innards to mush.

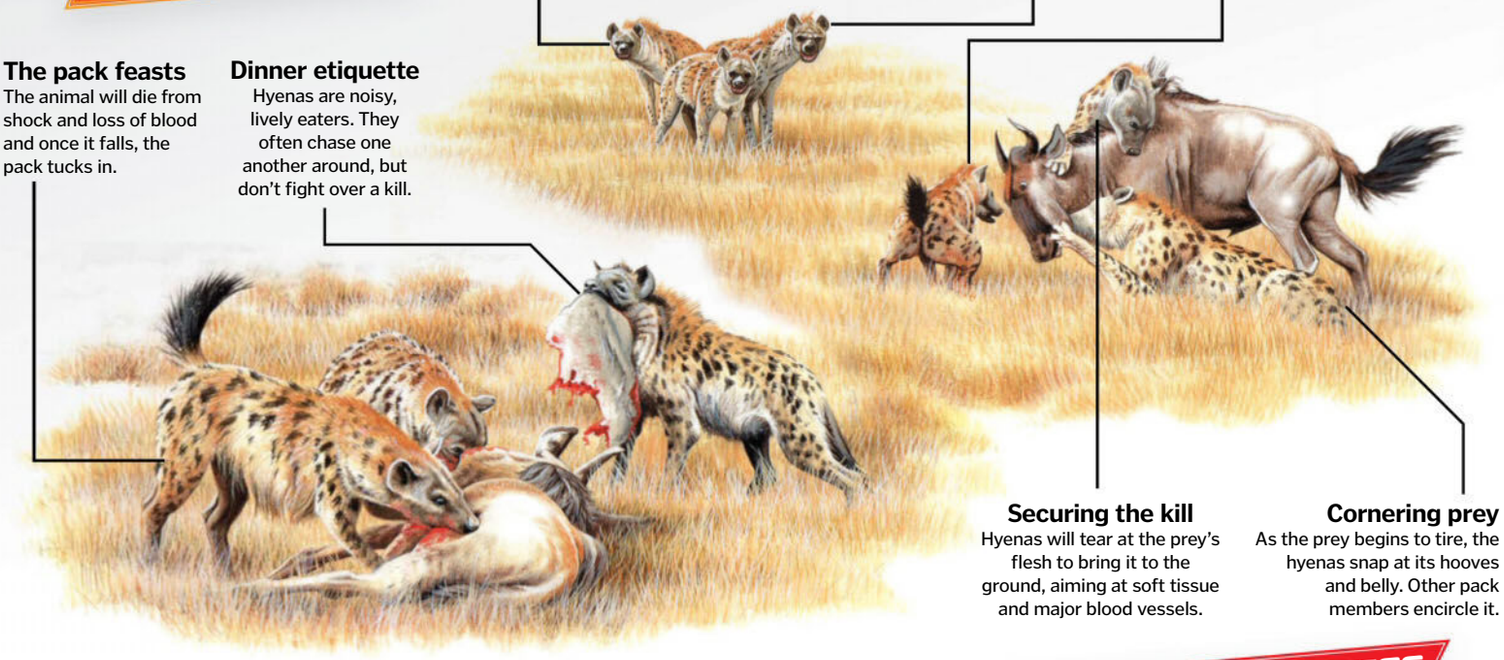
The animal kingdom also hosts opportunistic predators who sit back and wait until an ideal situation happens upon them. The lemon shark is one such beast. It positions itself in the middle of a large shoal of fish, but doesn't make its move until another predator enters the fray. As the other encroaching hunter launches an attack and panics the shoal, the lemon sharks are free to take their fill of fish from the chaos, a fine meal served with minimum effort.

A predator's environment can govern how it interacts with its prey, and how it is adapted to suit its place in the food chain. In water, predators must be quick and agile, hydro-dynamically shaped and capable of instant bursts of speed. The bluefin tuna is an excellent example of this. Unlike most fish it is warm-blooded, which helps its muscles work faster and more efficiently for nifty prey-snatching sprints though the water. Great white sharks are also well adapted. Their huge rows of pointed, serrated teeth are the best possible tool for tearing through skin and blubber, sawing up and devouring the prize before any scavengers get a look in.

On land, the cheetah is an excellent example of an animal perfectly suited to its hunting environment. On the open grassland plains of Africa, there is nowhere to hide, so the cheetah must be stealthy to get close to its hoofed prey. Once in position, the big cat can reach 100

A HYENA PACK ON THE PROWL

The ultimate scavengers are also skilled and speedy hunters



Communication
Hyenas have a large vocabulary of vocalisations, and will communicate with one another to coordinate a hunt.

Testing the herd
In small groups, the hyenas will charge at herds of prey, such as wildebeest, in order to single out the weaklings.

The chase
Once a single animal is chosen, the hyenas will doggedly attempt to run the prey down.

The pack feasts
The animal will die from shock and loss of blood and once it falls, the pack tucks in.

Dinner etiquette
Hyenas are noisy, lively eaters. They often chase one another around, but don't fight over a kill.

Securing the kill
Hyenas will tear at the prey's flesh to bring it to the ground, aiming at soft tissue and major blood vessels.

Cornering prey
As the prey begins to tire, the hyenas snap at its hooves and belly. Other pack members encircle it.

"One hyena distracts the mother, while the other moves in for the calf"

kilometres per hour during an incredible sprint, catching its prey unawares. The cheetah's long tail aids balance and its claws don't retract to provide traction on the dry soil.

Where larger animals have the advantage of size and power, smaller critters have to develop more cunning ways of taking down prey. Being toxic is a helpful trait, as in the case of the black widow spider. The venom used by this infamous arachnid paralyses its prey, which can include small mammals and reptiles.

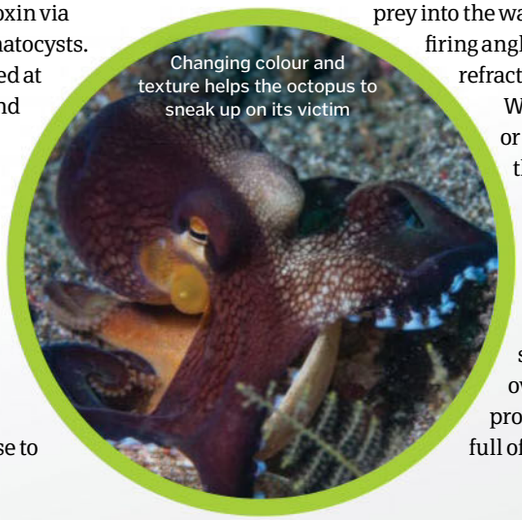
Similarly, the box jellyfish is shockingly toxic. Jellies are at the mercy of ocean currents and don't really look predatory, yet the sting of this gelatinous hunter can kill a human in seconds. It delivers a potent neurotoxin via stinging cells called nematocysts. The fish or shrimp is killed at the touch of a tentacle, and the jelly can get to work on digestion.

The common view of a predator is one that charges in with tooth and claw, and there are plenty of those on Earth. But the natural world is constantly showing us ingenious methods that animals use to secure their next meal. The electric eel for example, is capable of discharging thousands of tiny, battery-like cells to produce shocks of 600 volts. These fish stun their prey and tuck in.

The marine cone snail has another curious strategy. At night, it sneaks up on a resting fish, then quickly extends a proboscis, a nose-like organ shaped like a harpoon. It injects the fish with toxins to paralyse it and then swallows it whole.

One of the most ingenious predation methods belongs to the archerfish, the small Asian species that uses a water pistol to gun down its insect dinner. The fish compresses its gills to shoot a jet of water from its mouth and accurately knock prey into the water. It even adapts its firing angle to compensate for the refraction of light in water.

Whether it's speed, claws or deception that makes these predators so deadly, they all have one thing in common: the motivation to survive. Killer instincts and cunning skills have been honed over generations to produce a natural world full of elite hunters.



Changing colour and texture helps the octopus to sneak up on its victim

PREDATOR STATISTICS

40 KG

The amount of prey a brown bear eats per day when fattening up for hibernation

15 X MORE DEADLY...

...than a rattlesnake; the black widow spider's venom makes it a small but mighty predator

1 IN 3

The number of successful hunts in which a peregrine falcon catches its prey with the first strike

13%

The increase in success rate for a lion if it works in a team of two or more, rather than alone

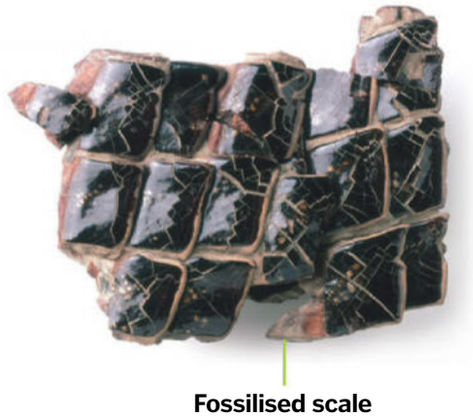
Why do fish have scales?

We get to the bottom of this slippery subject

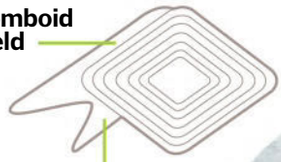
Thriving underwater requires some excellent morphological adaptations. One key attribute are scales: strong and durable plates that allow for fluid movement and protection from parasites, scrapes and predators.

There are many types of scale, depending on the fish's evolutionary history. For instance, sharks and rays have placoid scales, while ganoid scales are present on sturgeons and paddlefish. The properties of each scale type are suited to the fish's lifestyle and habitat. The scales all grow in the same direction, tapering towards the tail to make the fish streamlined. Fish with larger, heavier scales such as the Amazonian arapaima gain more protection but are often more restricted in their movement, whereas species such as eels have much smaller and sometimes microscopic scales that give more flexibility, but at the loss of an armoured exterior.

Depending on their classification, scales are either anchored to the body by attaching to bones, or by slotting into envelope-style grooves in the skin. Some scales grow with the fish, meaning they have the same number of scales their whole life, and some types are continually added and/or replaced. Many species of fish also sport a variety of scale types on different parts of their bodies.

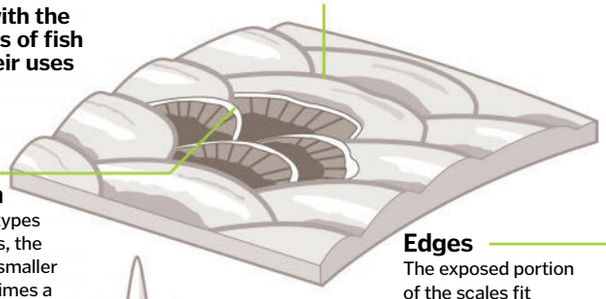


Fossilised scale
Lepidotes is an extinct ray-finned fish from the Jurassic period. There are fossilised remains of its large, oval scales.

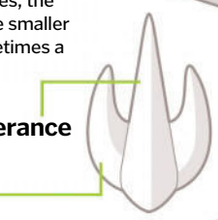


Know your scales

Get to grips with the different types of fish scales and their uses



Scale regeneration
When some fish types regrow lost scales, the new ones will be smaller in size and sometimes a different colour.



Edges
The exposed portion of the scales fit together neatly to make a smooth and flexible skin.

Toothed scales
The inner pulp of the placoid scale is supplied with blood, and it is surrounded with layers of dentine and enamel.

Base plate
This wide portion of the placoid scale anchors it to the shark's body.

Blue shark

Placoid scale
Also called denticles, these scales belong to sharks and rays. They fit together but don't usually overlap as much as other scales do.

Protective coating
Most fish have a layer of mucus over their scales to support their immune system and reduce drag in the water.

"Scales grow in the same direction to make the fish streamlined"

Epidermis
The outer layer of scales is called the epidermis, and covers most of the body. Below this, scales attach to a layer called the dermis.

Toothed edges
Small, comb-like extensions provide a rough texture to these ctenoid scales – 'cteno' means 'comb'.

Ctenoid scales
These tooth-shaped scales overlap like tiles on a roof. They're usually found on fish with spiny fin rays.

Perch

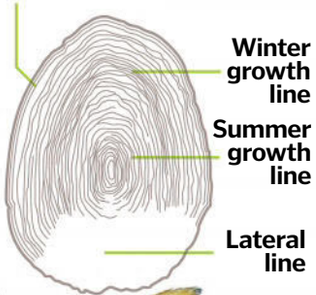
Shields
The outer layer of ganoid scales is made of ganoin, a shiny and enamel-like substance that strengthens the scales.

Ganoid scales
Strong, inflexible and diamond-shaped, these scales fit together with a peg-socket type joint. They are found in fossilised fish and species like sturgeons.

Sturgeon

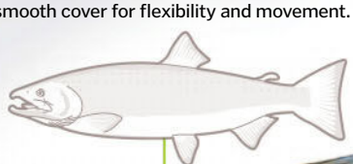
Cuticle
The fish's first line of defence, this outer layer has a mucus-like consistency and contains antibodies and proteins.

Age scales
As a fish grows, growth rings are formed on its scales. These can be counted to calculate a fish's age.

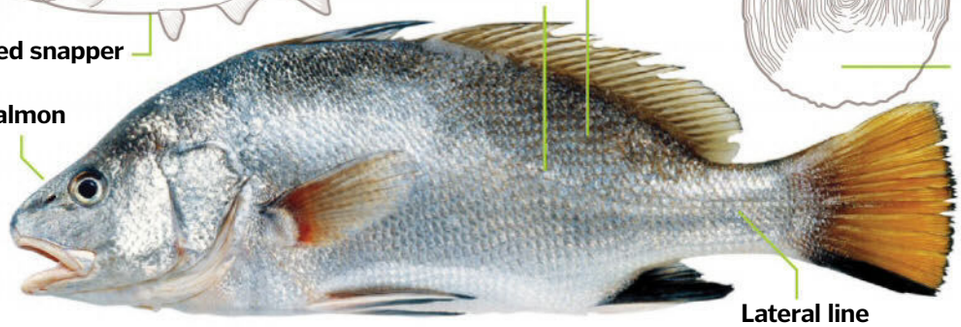


Cycloid scales
These rounded scales are found on species such as carp. The scales grow as the fish does, providing a smooth cover for flexibility and movement.

Distribution of scales
Scales are arranged in rows, which can be counted along the lateral line of a fish to help identify species.



Red snapper



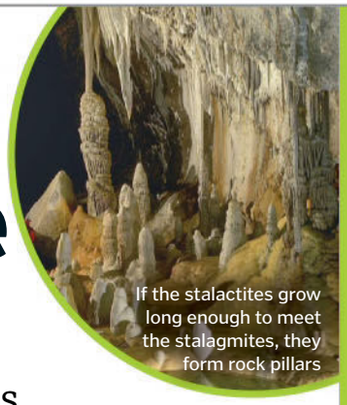
All shapes and sizes

Many different fish species have modified scales that serve specific purposes. Stingrays, for example, are members of the subclass Elasmobranchii – which also includes sharks and skates – and have placoid scales. These are also known as dermal denticles, due to their similarities with vertebrate teeth. The sharp barb at the end of the stingray's tail is a modified version of this scale structure, elongated and laced with venom for protection.

Some fish that sport ridges or spines, however, are covered in scutes. These shield-like plates can be found on certain species such as the pinecone fish, which as its name suggests, is protected with layers of strong scales to ward off any would-be predators.

Deciduous scales are another interesting modification. Just like their tree or shrub counterparts, these types of scales can be shed and then regrown. Species such as herring can use their deciduous scales to make a slippery escape from the grasp of bigger fish.

Stalagmite and stalactite formation


If the stalactites grow long enough to meet the stalagmites, they form rock pillars

Discover the development of these curious subterranean spikes

Struggling to tell the difference between these two formations? When you see the letter 'c' in stalactites, think 'ceiling', as they hang from the roofs of caves. And when you see the 'g' in stalagmites, think 'ground', as they rise from the floor like inverted icicles. Both structures are known as speleothems, and are formed over thousands of years, as water trickles through the cave and minerals are deposited layer upon layer.

Stalactites

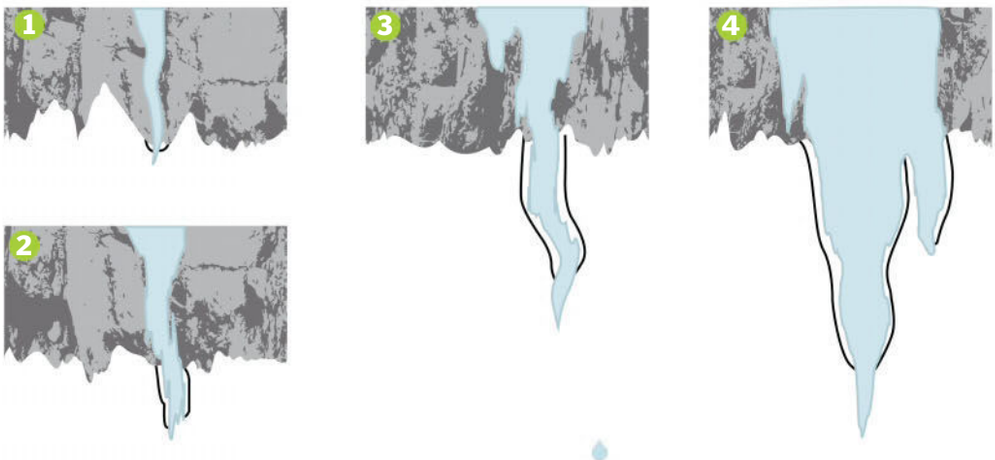
Steady drops of water build these structures downwards

1 Water drops
Water slowly filters through the many cracks and pores in the rock until it hangs as a drip on the cave ceiling.

2 Gradual build-up
Calcium carbonate is carried in the water – when it meets the air, it solidifies to form a tiny solid ring around the droplet.

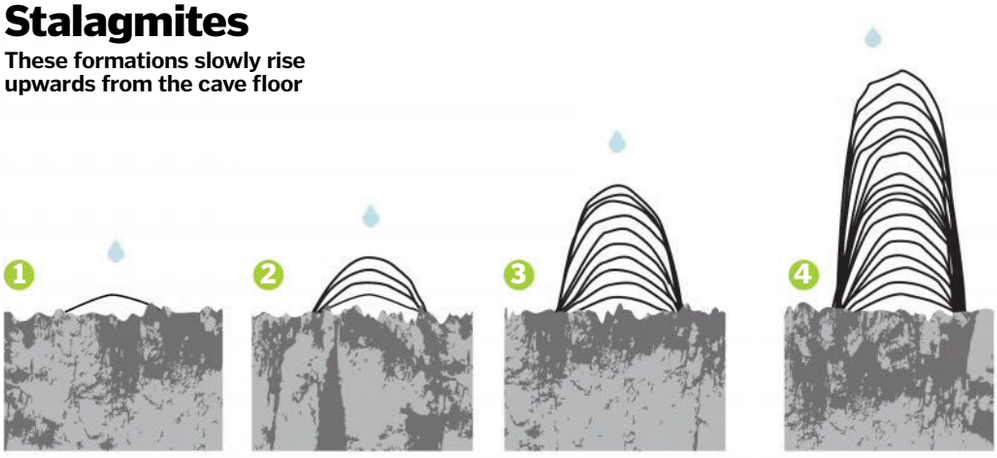
3 Layer upon layer
Straw stalactites form, where a long and thin deposit is built up with a hollow middle that water drips through.

4 Sturdier speleothems
As more and more mineral deposits build up on the stalactite, it gets longer, wider and more robust.



Stalagmites

These formations slowly rise upwards from the cave floor



1 Drops from above
As the same droplets that form stalactites hit the floor, calcium carbonate solidifies to form the base of a stalagmite.

2 Rounded shapes
The shape of a stalagmite is a rounded dome. As more drops hit the same patch of floor, the shape begins to build.

3 Slower 'growth'
The floor formations don't build up as quickly as stalactites, but the two structures can eventually meet to form a pillar.

4 Weather record
Analysing a stalagmite can reveal its age. Layers will be compact during wetter years and spaced apart for drier years.

What is soil made of?

The ingredients that form one of Earth's most important natural resources

In its simplest form, soil is a gritty mixture of ground-up minerals and decaying organic matter, such as leaf litter from the forest canopy. These raw ingredients are then mixed and churned together by the bugs and worms that live within.

The broken-up rocks that make up soil can come from the bedrock that lies deep below, or from other sources, where rocks, rubble and more soil is transported by forces such as rivers or glaciers.

There are six major types of soil, each with different mineral quantities and qualities. Clay soils are dense but high in nutrients, sandy soils are light, dry and relatively acidic, while silt soils are very fertile and hold plenty of moisture. Loam soils contain a balance of clay, sandy and silt soil types, while peat soil types are full of organic matter and chalky soils contain calcium carbonate and are therefore very alkaline.

Many different types of soil will build up in layers in any given spot, making what is known as soil horizons. These layers usually consist of organic matter in various stages of decay, depending on the locality.


Soil appears darker when there is more organic matter, or 'humus', present

Global wind patterns

Wind paths, ocean currents and even airplanes are governed by the same invisible force

The tell-tale spiral of 2011's hurricane Katia is whipped up, aided by the Coriolis effect

Winds in our atmosphere do not travel in straight lines due to a phenomena known as the Coriolis effect. As the Earth spins on its axis, the motion deflects the air above it. The planet's rotation is faster at the equator, because this is where the Earth is widest. This difference in speed causes the deflection – for example, if you were to throw a ball from the equator to the North Pole it would appear to curve off-course.

If Earth didn't spin like this, air on the planet would simply circulate back and forth between the high-pressure poles and the low-pressure equator. When the rotation of the Earth is added into the mix, it causes the air in the Northern Hemisphere to be deflected to the right, and air in the Southern Hemisphere to the left, away from the equator. As a result, winds circulate in cells.

It's this effect that causes the rotational shapes of large storms that form over oceans. The low pressure of cyclones sucks air into the centre, which then deflects thanks to the Coriolis force. This explains why cyclones that form in the Northern Hemisphere spin anti-clockwise, while in the Southern Hemisphere they rotate clockwise. The opposite is true of high pressure storms, or anticyclones, which rotate clockwise in the north and anti-clockwise in the south.

The Coriolis effect is so prevalent that it also governs the movement of long-range airborne objects such as airplanes and missiles. Pilots have to adjust their flight routes to compensate for the deflection.

Coriolis effect on water

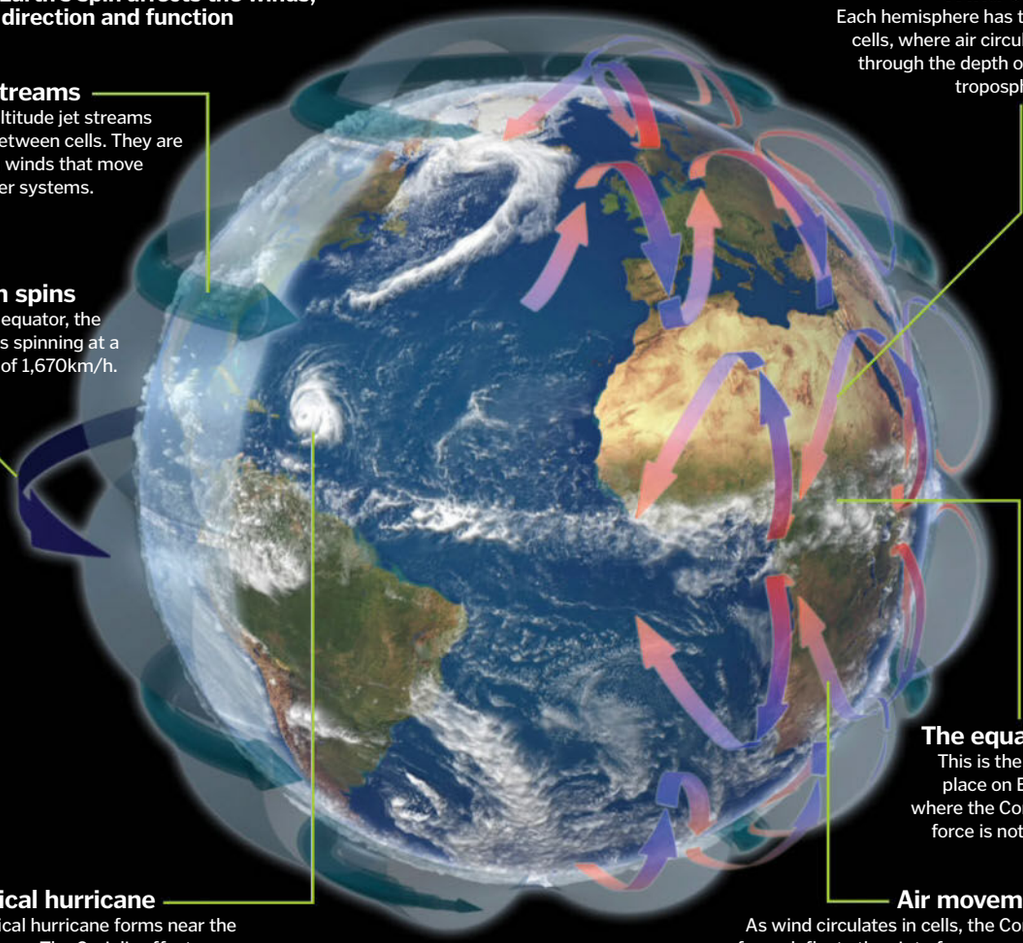
It is commonly believed that the Coriolis effect is the reason why water is perceived to spiral down the drain in one direction in the Northern Hemisphere, and in the opposite direction below the equator. However, the Coriolis effect isn't felt on such a small scale. The Coriolis effect does affect ocean currents, though.

Each ocean basin has a 'gyre' – a strong circulating current that moves around the basin. The deflected winds cause drag on the ocean surface, which translates into deep currents. Gyres in the Northern Hemisphere turn in a clockwise spiral, and they turn anti-clockwise in the Southern Hemisphere. There are no gyres crossing the equator so the Coriolis effect is not felt there.

Local factors such as the positioning of taps has more effect on water drainage direction

Global winds

How Earth's spin affects the winds, their direction and function



Jet streams
High-altitude jet streams flow between cells. They are strong winds that move weather systems.

Earth spins
At the equator, the Earth is spinning at a speed of 1,670km/h.

Tropical hurricane
A tropical hurricane forms near the Caribbean. The Coriolis effect contributes to the swirling system.

Wind cells
Each hemisphere has three cells, where air circulates through the depth of the troposphere.

The equator
This is the only place on Earth where the Coriolis force is not felt.

Air movement
As wind circulates in cells, the Coriolis force deflects the air to form prevailing winds such as the trade winds.

12 SURPRISING FACTS ABOUT THE SOLAR SYSTEM

Our cosmic neighbourhood is a much stranger place than you think...

1 Jupiter is a planet killer!

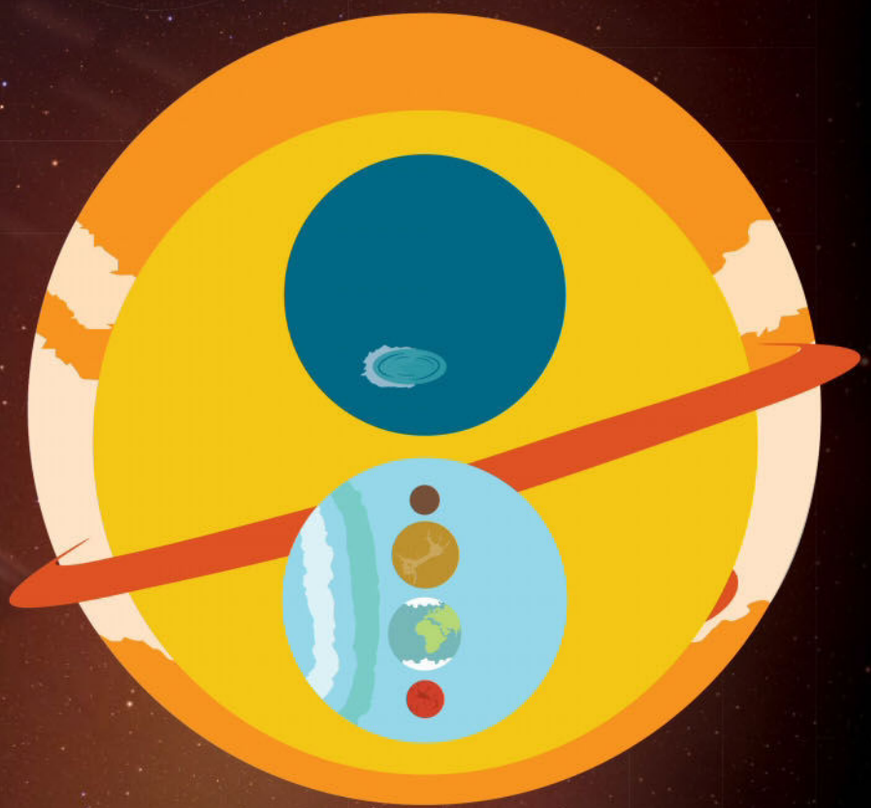
As astronomers continue to find other planets and Solar Systems beyond our own, one thing is becoming abundantly clear – ours may be unique. Other systems appear to not only have planets in tighter orbits than our closest planet to the Sun, Mercury, but many also have much larger rocky planets, known as super-Earths.

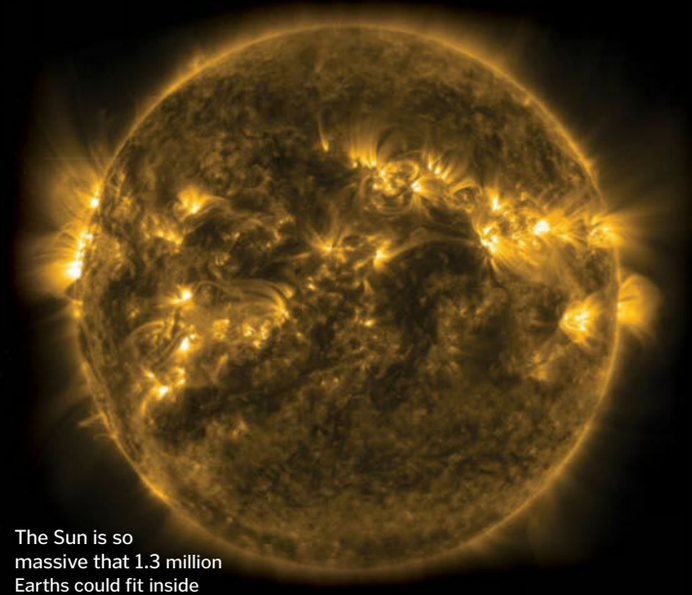
Why is that not the case here?

The reason might be down to Jupiter. We already think the gas giant had a major effect on the early Solar System; its gravity was so strong that it prevented a planet forming between itself and Mars, giving rise to the Asteroid Belt. Now astronomers think that Jupiter may have swung through the young Solar System like a wrecking ball, disturbing the formation of other worlds – and even kicking some whole planets out.

Known as the Grand Tack theory, it suggests that Jupiter migrated inwards before the formation of other worlds like Saturn. Here, its gravitational pull would have acted like a slingshot, throwing newly forming planets out. Later, the formation of Saturn would have stabilised Jupiter's orbit beyond Mars, leaving the inner Solar System calm enough for the current rocky planets – Mercury, Venus, Earth and Mars – to form.

This helps to explain the lack of super-Earths in our Solar System, but it could also mean that our planetary system is relatively rare. This could have implications for finding planets that formed in a similar way to Earth, which is one of the key goals for planet hunters at the moment.





The Sun is so massive that 1.3 million Earths could fit inside

2 The Sun makes up 99% of all the mass in the Solar System

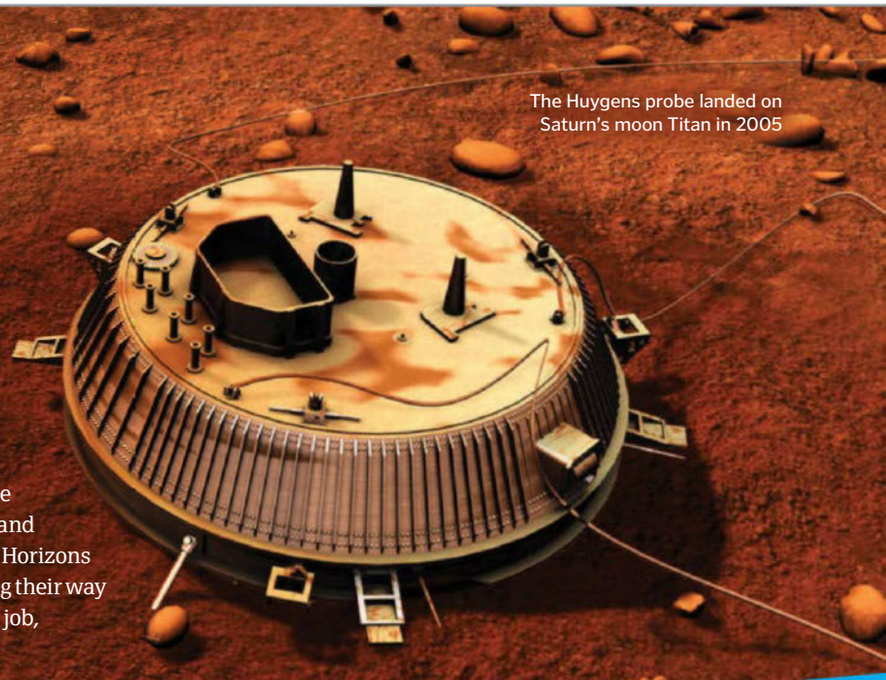
There are many thousands of bodies in the Solar System, ranging from large planets to small asteroids and comets. But even adding these together, they pale in comparison to the Sun. The biggest world aside from this ball of gas is Jupiter, about 140,000 kilometres across. The Sun, meanwhile, is about 1.4 million kilometres wide. Its mass is about two million trillion trillion kilograms – 330,000 times that of Earth – which makes up 99.86 per cent of the Solar System's total mass!

The asteroid belt is not as dense as you might think

3 Flying through the asteroid belt is easy

In *Star Wars: The Empire Strikes Back*, an asteroid belt is depicted as a dense region of space rocks that is incredibly difficult to navigate. That may be true in a galaxy far, far away, but it's nothing like that in our Solar System. The asteroid belt between Mars and Jupiter contains around 750,000 asteroids. That may seem like a lot, but they are separated from each other by an average of 970,000 kilometres. If you flew through the asteroid belt you would be unlikely to even see one, let alone have to dodge any to travel through.

4 Bits of humanity are everywhere



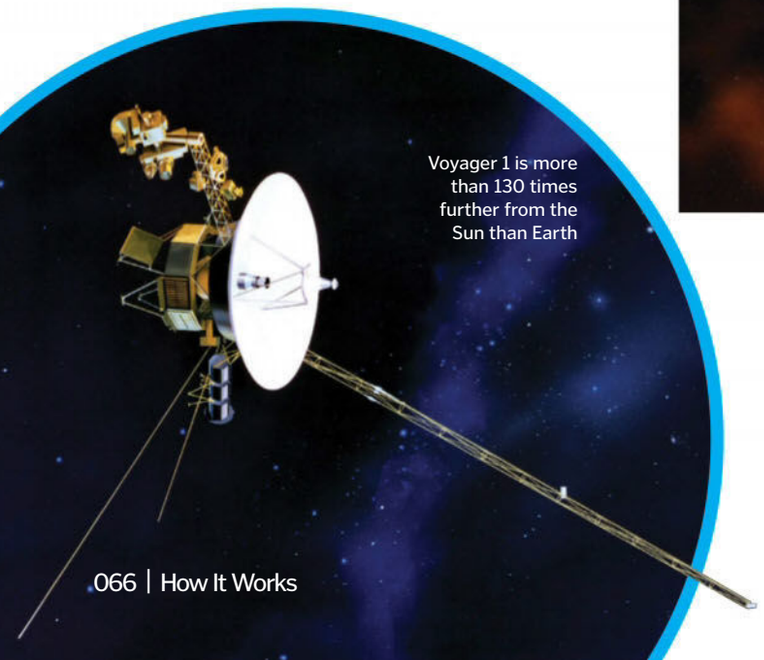
The Huygens probe landed on Saturn's moon Titan in 2005

We've been a space-faring species for over half a century now, and in that time we've managed to explore an impressive amount of the Solar System. We've sent spacecraft to all of the major planets, as well as three dwarf planets, and several comets and asteroids.

If that's not impressive enough, we've also landed on a total of seven bodies, and crash-landed spacecraft on others. Currently, man-made machines – both alive and dead – reside on the Moon, Mars, Venus, Saturn's moon Titan, asteroid Eros and comet 67P/Churyumov-Gerasimenko. We've also returned samples from an asteroid, Hayabusa, impacted another asteroid, and even sent a probe into the atmosphere of Jupiter. That's not even counting the various spacecraft we have orbiting the Sun, and the five spacecraft – the Voyager and Pioneer probes, and the New Horizons spacecraft – currently making their way out of the Solar System. Good job, humanity.

5 Voyager 1 left the Solar System

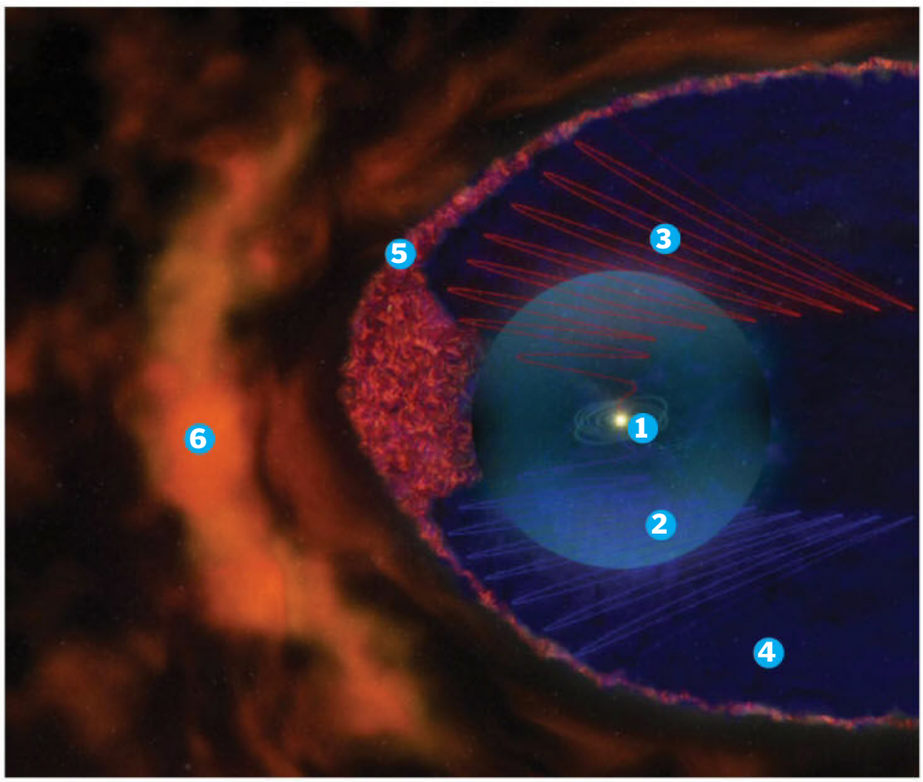
In September 2013, scientists broke into celebration. After a number of false dawns, it was confirmed that Voyager 1 – our most distant emissary – had left the Solar System, the first human spacecraft ever to do so. This intrepid spacecraft was launched in 1977 on a mission to explore the outer planets. After this, it continued to the edge of the Solar System. At a distance of 19 billion kilometres from our Sun, it was confirmed that it was outside the solar bubble, the heliosphere, and had entered interstellar space. The true edge of the Solar System is debated, though. Some say its influence extends to more than three light years, yet Voyager 1 has travelled just 0.002. More on that later...



Voyager 1 is more than 130 times further from the Sun than Earth

Our Solar System's limits

How the Sun's influence extends to interstellar space



1 Launch
Voyager 1 was launched from Earth, 150 million kilometres from the Sun, on 5 September 1977.

2 Termination shock
The solar wind flows freely until the boundary, or termination shock, where it slows sharply.

3 Heliosphere
This bubble-like region is created by the Sun's solar winds that extend far out into the Solar System.

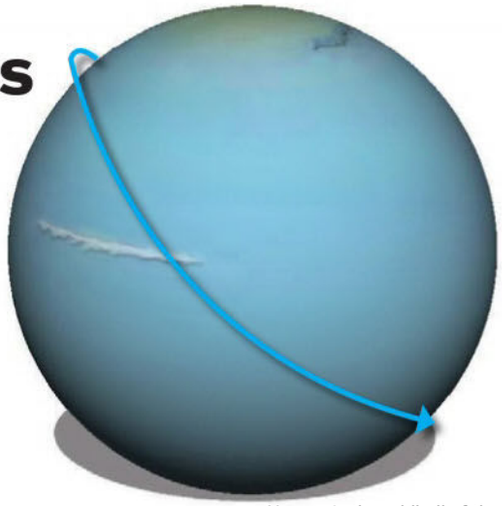
4 Heliosheath
Between the termination shock and the heliopause is a transitional region called the heliosheath.

5 Heliopause
This is the edge of the heliosphere, the boundary between the interstellar medium and the solar wind.

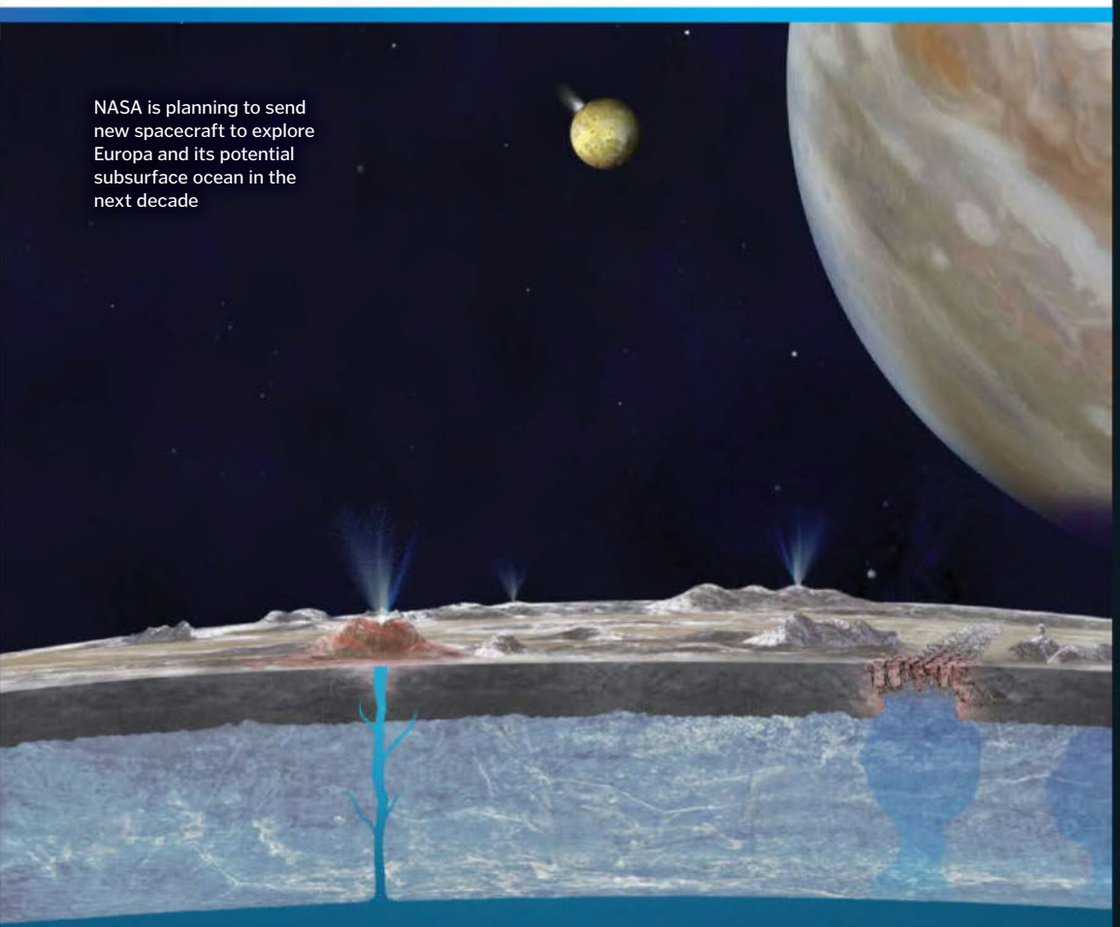
6 Bow shock
The Sun's influence is thought to produce a 'shock wave' where it meets the interstellar medium.

7 Uranus rotates on its side

All of the planets in the Solar System rotate with an axis at almost a right angle to their orbital plane around the Sun – except Uranus. For some reason, the spin axis of this planet is tilted by 98 degrees (Earth's is 23). This means that it rotates on its side, with its poles pointing along its orbital plane. Initially, astronomers thought this might have been caused by a single impact early in the life of Uranus. Now, however, it's thought multiple impacts may have been the culprit.



Uranus is the oddball of the planets, spinning on its side



NASA is planning to send new spacecraft to explore Europa and its potential subsurface ocean in the next decade

8 There's a lot of water

How Earth got its water remains a bit of a mystery. We think comets or asteroids in the early Solar System may have transported it here, but we aren't exactly sure how it happened. One thing we are clearer on, though, is that Earth is not the only wet place. Towards the end of 2015, it was confirmed that Mars still has dribbles of liquid water on its surface – and we think it could have had a vast ocean a few billion years ago. Other planets, including Jupiter and Venus, have large amounts of water vapour in their atmosphere. But it is a select few moons that are perhaps most of interest. Three of Jupiter's large moons – Europa, Ganymede and Callisto – in addition to Saturn's moon Enceladus, are all thought to have vast subsurface oceans, possibly containing more water than there is on Earth. And there could be more hidden oceans elsewhere awaiting discovery.

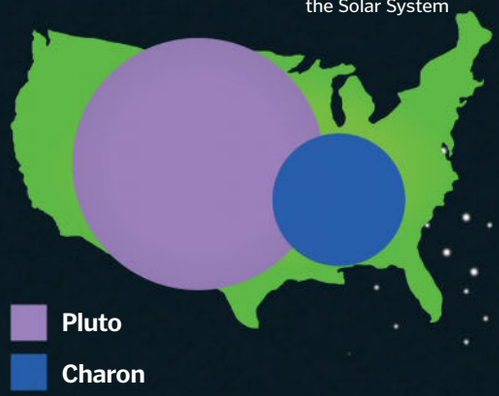
6 Pluto is smaller than the United States

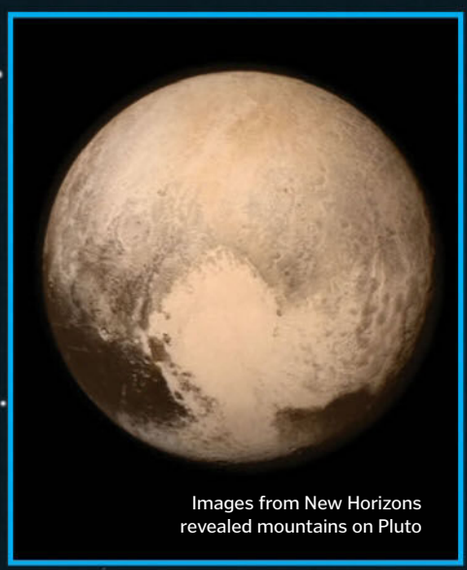
In 2008, Pluto lost its status as the ninth planet of the Solar System, because astronomers found another of a similar size – Eris. Realising there could be many more objects of this size, they demoted Pluto, for fear of having a rather hefty planet mnemonic to remember.

Pluto is indeed small, relatively speaking, spanning roughly 2,372 kilometres. For comparison, the distance across the US is approximately 4,800 kilometres, so if you were to place Pluto on top of the US, it would easily fit from end to end.

Don't let that take anything away from Pluto though. This dwarf planet is absolutely fascinating, as highlighted by the recent New Horizons mission. Once thought to be a barren world, we now think it was recently geologically active and may even have ice volcanoes on its surface.

Pluto is the 17th largest object in the Solar System



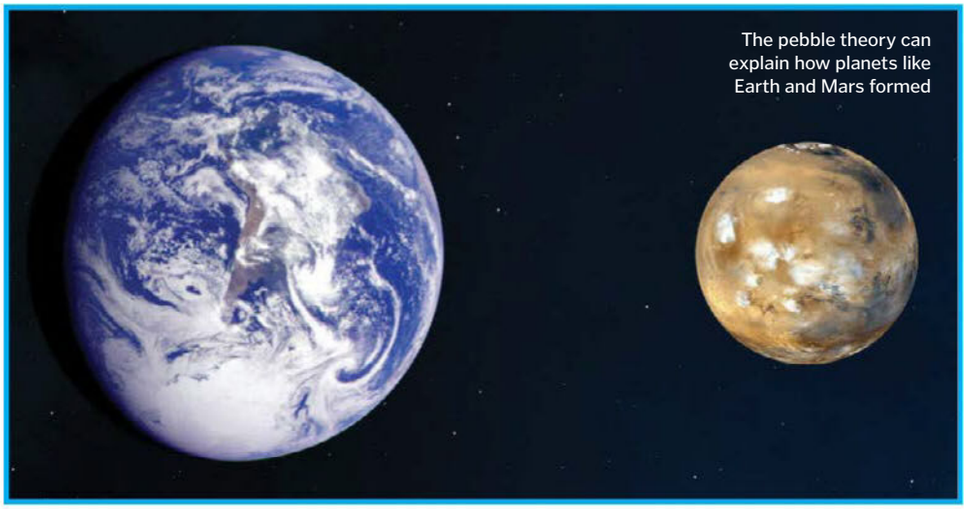


Images from New Horizons revealed mountains on Pluto

9 'Pebbles' formed the planets

How the planets in our Solar System formed is a great mystery. Although most experts agree that gas and dust stuck together to form larger bodies, the details of this process remain unclear.

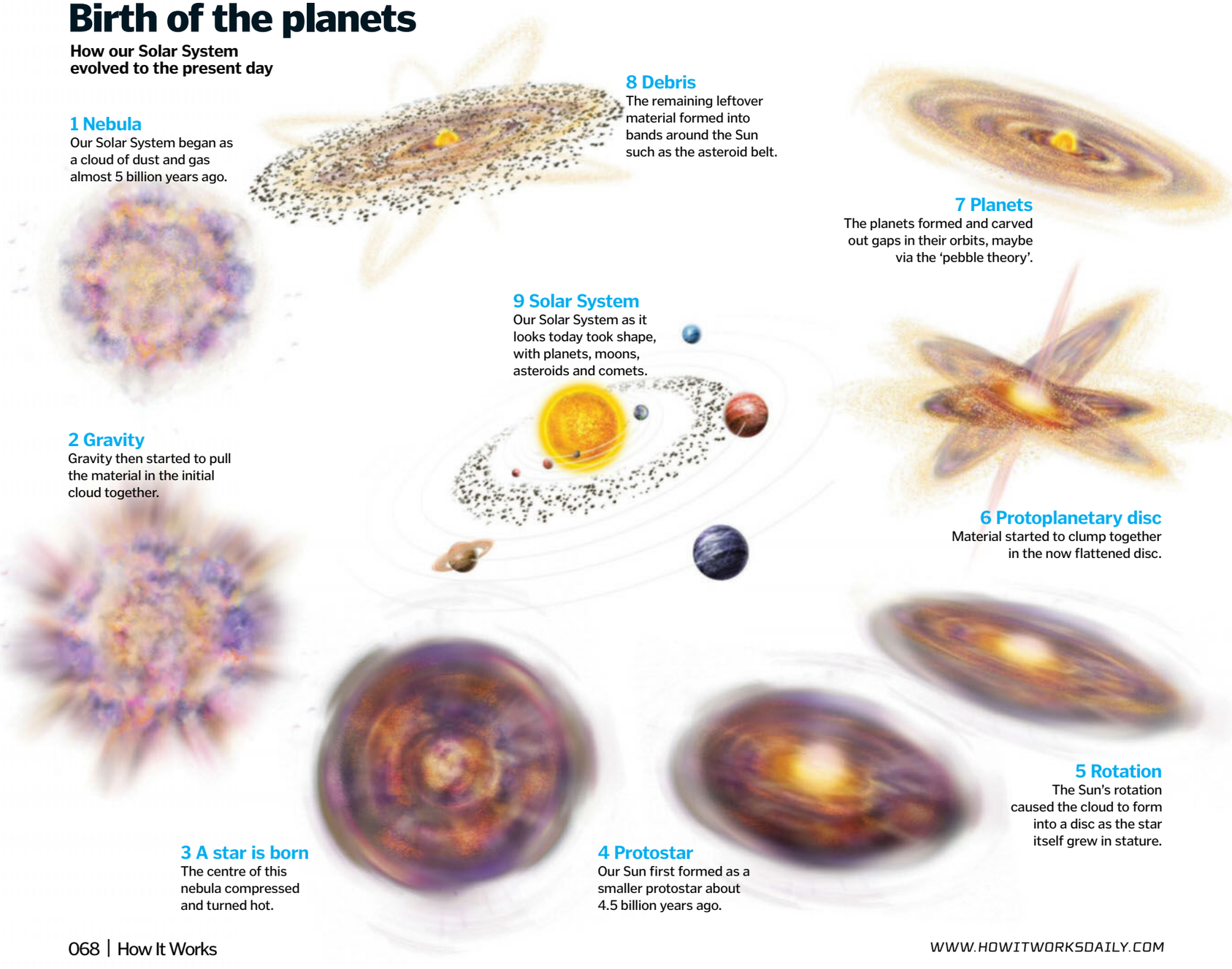
A promising model for the formation of the planets is the 'pebble theory'. Unlike other proposals, it explains why Mars is smaller than Earth, and how the gas giants formed first. The theory states that all bodies formed via small 'pebbles' gradually grouping together over time. As the main bulk of the object grew, it kept attracting these small pebbles. Rather than previous theories of accretion, which suggested similarly sized objects grouped together, this theory explains how one dominant objects sweeps up all material, allowing growth 1,000 times faster than previously theorised.



The pebble theory can explain how planets like Earth and Mars formed

Birth of the planets

How our Solar System evolved to the present day



1 Nebula
Our Solar System began as a cloud of dust and gas almost 5 billion years ago.

2 Gravity
Gravity then started to pull the material in the initial cloud together.

3 A star is born
The centre of this nebula compressed and turned hot.

4 Protostar
Our Sun first formed as a smaller protostar about 4.5 billion years ago.

5 Rotation
The Sun's rotation caused the cloud to form into a disc as the star itself grew in stature.

6 Protoplanetary disc
Material started to clump together in the now flattened disc.

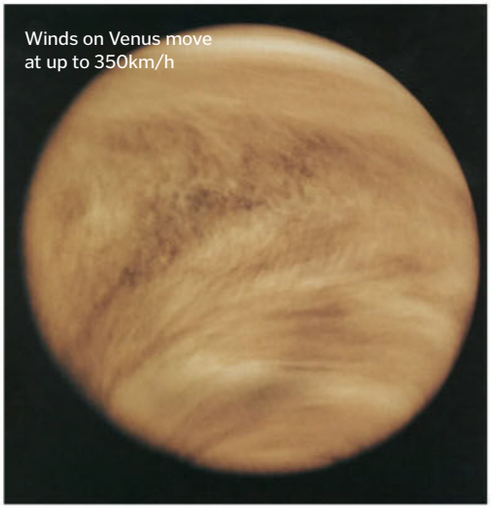
7 Planets
The planets formed and carved out gaps in their orbits, maybe via the 'pebble theory'.

8 Debris
The remaining leftover material formed into bands around the Sun such as the asteroid belt.

9 Solar System
Our Solar System as it looks today took shape, with planets, moons, asteroids and comets.

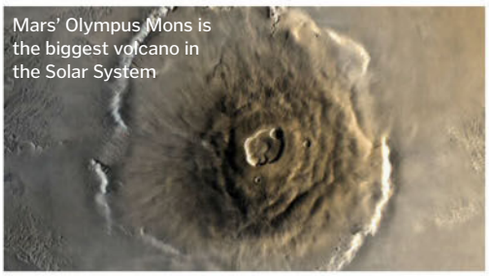
10 The most Earth-like place is on Venus

Despite being the second closest planet to the Sun after Mercury, Venus is the hottest planet owing to its extremely thick atmosphere, a scorching 462 degrees Celsius. It also has a surface pressure equivalent to standing at the bottom of an ocean on Earth. But between 50 and 60 kilometres above the surface, the atmospheric pressure and temperature are the same as our planet. These conditions are the most Earth-like in the Solar System – apart from Earth, of course.



Winds on Venus move at up to 350km/h

11 There's a volcano on Mars as big as Arizona



Mars' Olympus Mons is the biggest volcano in the Solar System

Think Everest is big? Think again, because there's a dormant volcano on Mars that dwarfs any of our biggest mountains. Named Olympus Mons, this shield volcano is about 624 kilometres across, roughly the size of Arizona, and about 25 kilometres high. It is the largest volcano or mountain in the entire Solar System. One reason for its size might be the lack of a shifting crust on Mars, which allowed lava to pile up into this massive formation.

12 The Oort Cloud is absolutely huge

As mentioned earlier, Voyager 1 is now believed to be beyond the main influence of the Sun and in interstellar space, at a distance beyond 20 billion kilometres. But our Sun's influences goes much, much further. At the edge of the Solar System, where Pluto orbits, is the Kuiper Belt. It extends from 30 to 50 astronomical units (AU; 1 AU is the Earth-Sun distance) and contains dwarf planets such as Pluto and Eris, as well as billions of comets and asteroids over two kilometres across. But beyond this belt is the Oort Cloud. This mysterious region is thought to extend up to a whopping 200,000 AU (more than three light years), with potentially trillions of objects larger than one kilometre left over from the formation of the Solar System, mostly comets. It would be many, many millennia before Voyager 1 could get anywhere near to exploring the edge of this.

The Oort Cloud extends far beyond the Kuiper Belt at the edge of the Solar System

30 YEARS
Time it would take a spacecraft with a solar sail – one of the fastest current propulsion systems – to reach the Oort Cloud

2
The Oort Cloud may have two regions

1932
Year the Oort Cloud was first theorised

4.37 LIGHT YEARS
Distance from the closest star, Alpha Centauri, to our Sun

5 EARTHS
Estimated mass of the Oort Cloud

3 LIGHT YEARS
Distance the Oort Cloud could extend to

What is the Pacman Nebula?

Nearly ten thousand light years away, the Pacman Nebula's game is to give birth to new stars

The Pacman Nebula is a reminder of many childhoods spent at the arcade, but to astronomers it's a place to get an unhindered view of star birth in action. They can observe how stars are formed from a cloud of mostly hydrogen and helium gas, sprinkled with cosmic dust.

Residing some 9,200 light years from our planet, in the Cassiopeia constellation, the Pacman Nebula was originally discovered in 1883 by astronomer Emerson Edward Barnard. The reason why it got its name isn't immediately obvious from this picture, but when you look at it through the eyepiece of a telescope, it looks like a fuzzy circle with a wedge chopped out of it – shaped just like Pac-Man ready to chomp down on some Pac-Dots!

The Pacman Nebula creates stars when parts of its gas condense. This image combines optical light (in red, orange and yellow) with X-ray observations (in purple). In the optical light, dense clumps where stars are forming can be seen. In the X-rays, elements such as magnesium, sulphur and silicon have been found. These are the telltale signs that the Pacman Nebula was once home to an exploding star called a supernova.

The Pacman Nebula (NGC 281) is home to young stars up to 3 million years old

The biggest things in the universe

HERE ARE THREE GIANTS OF THE COSMIC PLAYGROUND

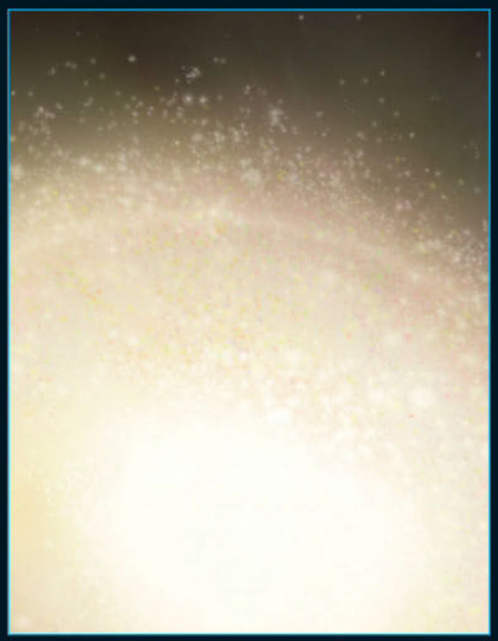
The 'Great Wall' of space

Galaxies aren't just spread randomly through space, but group together in clusters, which themselves group together in superstructures that are billions of light years across. The largest known superstructure is the Hercules-Corona Borealis Great Wall, which is more than 10 billion light years across and up to 50 times larger than typical galaxy clusters.

The Hercules-Corona Borealis Great Wall is too big to image, but looks similar to MACS J0717.5+3745

Galaxy IC 1101

Our Milky Way is about 100,000 light years across, but the largest galaxy in the universe, known as IC 1101, could be a whopping 4 million light years across if measured to include its huge halo of diffused light. It lives at the centre of a galaxy cluster called Abell 2029, where it was able to merge with many other galaxies to grow so large, and is a billion light years away from the Milky Way.



The largest galaxy in the known universe is 4 million light years across

Stellar nursery NGC 604

The biggest star-forming nebula currently known to astronomers is not in the Milky Way, but can be found in the nearby Triangulum Galaxy instead. This nebula, which is known as NGC 604, is 1,500 light years across, which makes it around 40 times larger than the famous Orion Nebula. Its biggest newborn stars are 120 times the mass of our Sun.

The Hubble Space Telescope's view of NGC 604, an enormous nebula where stars are born

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Space weather

Get the forecast for the Sun's explosive activity and how it affects us on Earth

The Sun, and the vast vacuum of space surrounding it, may seem pretty peaceful to us on Earth, but it is actually alive with violent activity. Although you might not hear about it on television forecasts, it's the source of a variety of space weather, and there are some very important reasons why we should be aware of it. Throughout its 11-year solar cycle, the big ball of hot plasma at the centre of our Solar System bombards our planet with solar winds. During periods of peak activity, this can disrupt many of the technological systems we rely on for communication, navigation and more. Read on to discover how...

Solar wind

Streams of charged particles called plasma are constantly escaping the surface of the Sun, as the star's powerful gravity fails to contain them. Known as solar wind, it can reach speeds of up to 800 kilometres per second as it hurtles towards Earth, where it continuously batters our planet's magnetic field. Solar wind is so powerful that it is believed to have stripped away the atmospheres of many other planets, such as Mercury, but Earth's relatively strong magnetic field is keeping it at bay.

How does space weather affect us?

While the magnetosphere provides us with some protection from space weather, its effects can still impact our daily lives. Geomagnetic storms interfere with Earth's upper atmosphere, interrupting radio communications, disrupting Global Positioning Systems (GPS) and even inducing electric currents at ground level, resulting in disruptions to power grids and widespread blackouts.

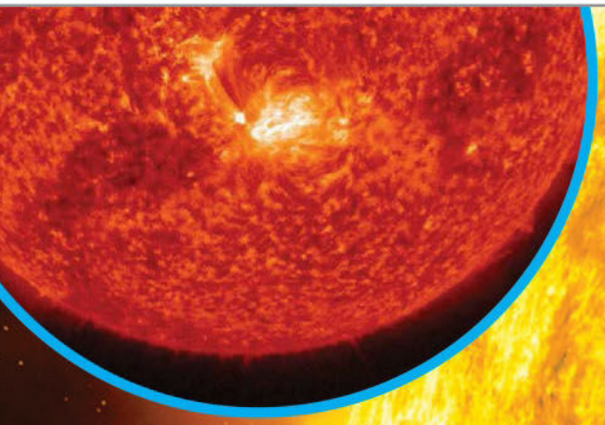
Increased levels of solar radiation also pose a threat to spacecraft and astronauts in orbit and can even reach aircraft travelling at high altitudes, presenting health risks for passengers. To minimise these effects, space weather is constantly monitored so that steps can be taken to prepare for extreme events.

Not all of the effects of space weather are bad, though. Auroras, such as the Aurora Borealis (also known as the Northern Lights), are the result of solar wind entering Earth's atmosphere above the magnetic poles. As the charged particles collide with gas particles in the atmosphere, they light up to create a colourful display in the sky.

Auroras are certainly the most visually pleasing effect of space weather

Earth's protection

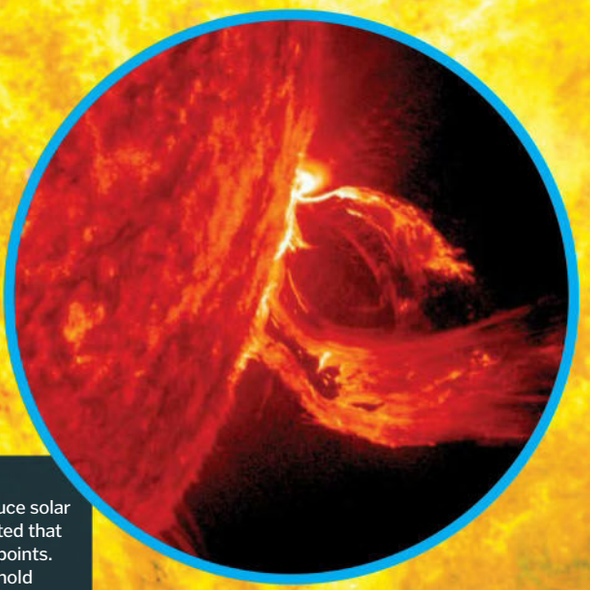
Earth's magnetic field forms a magnetosphere, which acts as a shield to protect our planet from the effects of space weather. However, the constant battering of solar winds has had a dramatic impact on its shape, compressing the side closest to the Sun and stretching out the other. Sometimes, the solar winds can disconnect the magnetic field lines on the night side, and when they snap back into position, they push charged particles back towards Earth's upper atmosphere.



"Throughout its 11-year solar cycle, the Sun bombards our planet with solar winds"

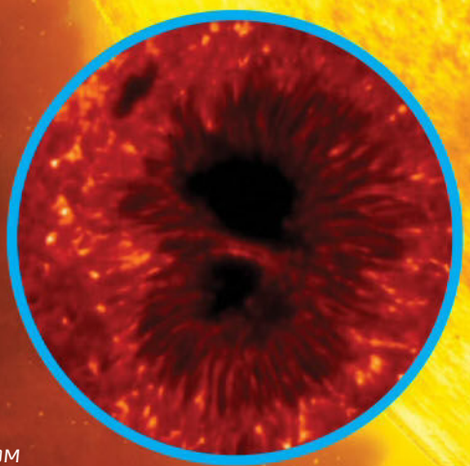
Solar flares

When twisting magnetic field lines in sunspot regions cross and reconnect with one another, they cause massive explosions called solar flares. The energy released is the equivalent of millions of 100-megaton hydrogen bombs exploding at the same time, sending huge amounts of radiation out into the Solar System. The radiation emitted spans across the entire electromagnetic spectrum, from radio waves to X-rays and gamma rays, and travels at the speed of light to reach Earth in just eight minutes.



Coronal mass ejections

The magnetic field lines that produce solar flares sometimes become so twisted that they snap and reconnect at other points. The gaps that form can no longer hold plasma on the Sun's surface, and release billions of tons of it into space as a 'coronal mass ejection'. Their speed can vary greatly, meaning they can reach Earth in a matter of hours or days, and when they do their own magnetic field slams into Earth's to generate geomagnetic storms.



Sunspots

Magnetic field lines breaking through the Sun's surface create dark regions known as sunspots. As heat is inhibited from rising up from the solar interior, these regions are comparatively cooler than the rest of the Sun's surface, but still reach scorching temperatures of around 3,500 degrees Celsius. Sunspots are usually found near to the Sun's equator and are the source of most extreme space weather. The number of them varies throughout the 11-year solar cycle, creating periods of peak activity.

Learn more

Visit **www.spaceweather.com** to get the latest forecast and keep up to date with the current conditions in space. Additional space weather information can also be found at the Space Weather Prediction Center's website, **www.swpc.noaa.gov**.

Astronaut Tim Peake's photograph of the Alps from onboard the ISS, where Earth is always in sight, but out of reach

Deep space training

The only way to prepare for isolation is to experience it

Inflatable loft
Extra space can be provided with inflatable structures, giving the astronauts more room.

Airlock
There is no escape from the confinement; trips outside require protective clothing and meticulous planning.

Compact living
Crews living away from Earth will have to cope with confined conditions and little privacy.

Workstation
Days off are not always an option; crews will need to be prepared to perform essential tasks.

Medical station
There is no emergency evacuation in space, so the crew will need to be able to cope alone.

Food supply
The range of foods available will be limited, and astronauts may end up eating the same things again and again.

Journeying to Mars on Earth

In 2010, six men were locked inside a structure with a volume of just 550 cubic metres, and they pretended to fly to Mars and back for the next 520 days. This may sound bizarre, but Mars-500 was an important experiment.

There is no room for a mistake hundreds of days into a trip to Mars; the astronauts will have no easy way out, so before they set off we need to be sure that people can cope. The crew of this imaginary voyage performed the monotonous routines that would be required to take a ship from Earth to Mars, and when they arrived, they docked with an orbiter, and even took a fake lander down to a simulated Martian surface. In 2015, NASA began a similar experiment in Hawaii to simulate living on the isolated surface of Mars itself.

The Mars-500 crew after almost a year in isolation

Preparing for space

Astronauts have to be physically fit, but mental preparation is just as important

Space is vast, empty and lonely. Onboard a ship with just a handful of other human beings for company, journeys to other worlds in our Solar System will test more than just the physical bodies of the astronauts. They will need to be able to cope with extreme isolation.

No human being has ever travelled more than 400,171 kilometres from the surface of the Earth, little more than a couple of days away. People have spent months and months on the International Space Station, but home is just below and always in sight – travelling to other planets will be very different.

Mars is 225 million kilometres away on average. It will take a crew seven months to get there, and they will be very, very alone. They will only have one another for support, there will be no emergency evacuation, and they will not be able to step outside and feel the air on their skin. They will have to work in a harsh environment, completing monotonous tasks day after day, and although they will be on one of the most exciting missions in the history of humankind, it is going to be a tough and gruelling journey.

Astronauts are already thoroughly screened to ensure that they are able to withstand the stresses and challenges of space travel, but extra precautions are being taken before a crew makes this bold leap into the unknown. Back here on Earth, trainee crews are simulating the isolation of long-term space travel in specially designed habitats to make sure they are up to the challenge that lies ahead.

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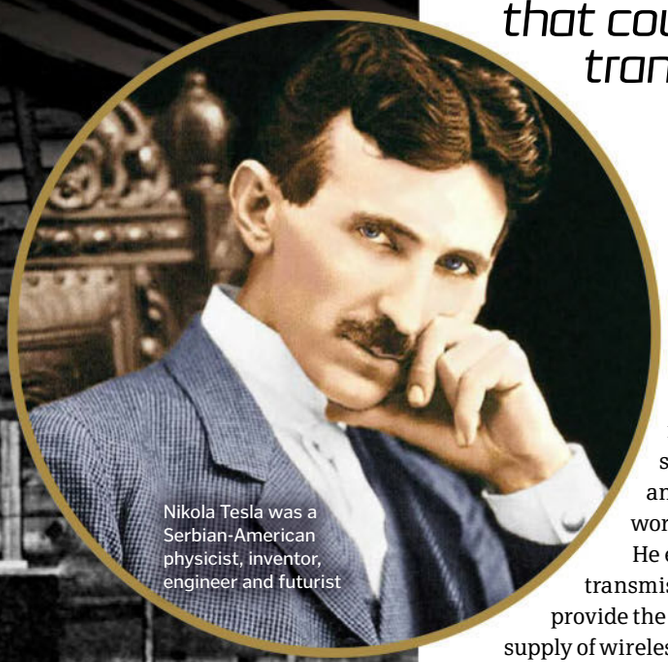
The Tesla coil

How one of history's greatest inventors produced a spectacular light show

In this double-exposure photograph, Tesla appears to sit in his Colorado Springs laboratory while a Tesla coil sends sparks through the air

"Tesla began to build a 57-metre tall tower that could wirelessly transmit energy"



Nikola Tesla was a Serbian-American physicist, inventor, engineer and futurist

After inventing the ground-breaking alternating current (AC) motor in 1887 – the device that is used to power many of the electrical gadgets that we use in the modern day – Nikola Tesla set his sights on a different and more challenging dream: a world without wires.

He envisioned a series of giant transmission towers that could provide the entire globe with an endless supply of wireless electricity, and his first step towards achieving this dream was the Tesla coil. This revolutionary device was capable of producing high voltage, high frequency AC electricity that could be sent through the air.

The Tesla coil consisted of two main parts: a flat primary coil and a taller secondary coil, both made of thick copper wire. When switched on, a transformer connected to the mains power supply converted the low voltage power into high voltage power, stepping it up to thousands of volts. It was stored in a capacitor, just like a modern battery, and when it was fully charged, it was sent flowing through the primary coil.

This created a strong magnetic field, which generated an electric current in the secondary coil through electromagnetic induction. Energy quickly flowed back and forth between the two coils several hundred times per second, building up charge in an additional capacitor attached to the secondary coil. Eventually, the charge in this capacitor became so great that it escaped, sending sparks flying through the air and illuminating light bulbs that were several metres away.

After wowing onlookers with this spectacular light show, Tesla began to build a 57-metre tall tower that could wirelessly transmit energy across great distances using this technique. However, construction was soon abandoned when he failed to secure enough funding for the project. Although he fell short of achieving his dream of a wireless world, variations of his Tesla coil are still used in radios and televisions to this day.

The Magnifying Transmitter tower was designed by Tesla to deliver wireless electricity around the world

The Palais Garnier opera house

Check out the building that inspired Leroux's *Phantom Of The Opera*

Emperor Napoleon III commissioned the construction of the grand opera house

Formally opened in 1875, this grand opera house was designed by architect Charles Garnier. Built in the Neo-Baroque style, the lavish interior sports iconic, gilded staircases and lounges that allow vast numbers of people to flow through the foyer areas into the horseshoe-shaped auditorium. A huge chandelier hangs in the centre of the room, from which a counterweight fell to the ground in 1896, killing a construction worker. This, along with many more of the building's quirks, inspired Gaston Leroux's 1910 gothic love story, *The Phantom Of The Opera*.

When work began on the site in 1861, the workforces cleared hundreds of square metres of ground but were delayed in laying the concrete foundations. Despite many attempts to drain the site, the only way to stem the flow of water was to install a huge stone water tank. The pressure of the tank stops any more water rising, and it also stabilises the building. As well as inspiring Leroux's *Phantom*'s underground lake, Parisian firefighters now use the tank to practise swimming in the dark.

Inside the Palais

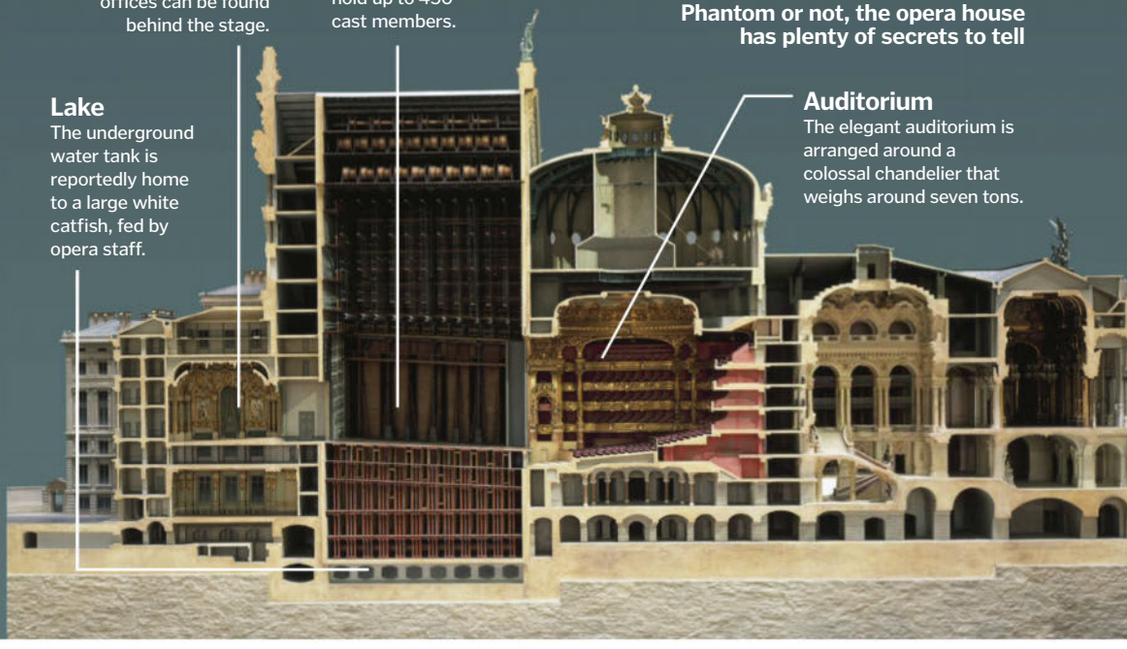
Phantom or not, the opera house has plenty of secrets to tell

Backstage
Rehearsal spaces, dressing rooms and offices can be found behind the stage.

Stage
The huge stage was built to hold up to 450 cast members.

Lake
The underground water tank is reportedly home to a large white catfish, fed by opera staff.

Auditorium
The elegant auditorium is arranged around a colossal chandelier that weighs around seven tons.



The world's tallest statues

Rounding up some of the most gigantic figures ever built

HENRY VIII by numbers

Shocking facts and figures about the infamous Tudor

Adored, feared, respected and reviled, Henry VIII is perhaps the most controversial king to have ever ruled England. He is best remembered for doing the unthinkable and breaking with the Catholic Church, instead declaring himself head of the new Church of England in 1534, in a period known as the English Reformation. The break was down to a dispute after the Pope had refused to annul Henry's marriage to his first wife, Catherine of Aragon, who had been unable to bear him a son. He turned his gaze to Anne Boleyn, and as they say, the rest is history.

Responsible for up to 72,000 EXECUTIONS

Estimates for the death toll vary greatly, but sources claim that anyone who refused to recognise Anne Boleyn as his lawful wife or who didn't agree with his break from the Catholic Church was killed, as well as anyone he took a general disliking to.

Henry was a well-respected musician and composer. Among his collection of musical instruments there were:

26 lutes

154 recorders

19 viols (similar to violins)

5 sets of bagpipes

65 flutes

1.88m

Henry towered over most of the other men in his court

60 HOUSES

Henry was a prolific palace builder. His most famous, Hampton Court Palace, had:

- ***A HUNTING PARK OF MORE THAN 445 HECTARES***
- ***KITCHENS COVERING 3,340 SQUARE METRES***
- ***A GARDEROBE (LAVATORY) THAT COULD SEAT 28 PEOPLE***

6 wives

Catherine of Aragon (m. 1509-1533)

Anne Boleyn (m. 1533-1536)

Jane Seymour (m. 1536-1537)

Anne of Cleves (m. Jan-July 1540)

Catherine Howard (m. 1540-1542)

Catherine Parr (m. 1543-1547)

Legitimate children 9

Henry's wives bore him many children, but only three survived past their first birthday. He also had an illegitimate child by his mistress Elizabeth Blount.

Mary I (1516-1558)

Elizabeth I (1533-1601)

Edward VI (1537-1553)

17 YEARS OLD

When he came to the throne, Henry was still a teenager. He reigned for 37 years until his death, aged 55.

Weight at death

Henry's appetite and inability to exercise due to ulcerated legs – the result of a riding accident – eventually took a toll on his waistline.

© WIKI; Thinkstock

Sikorsky MH-60 Black Hawk

Designed for special operations in hostile environments, this was a new kind of war machine, built for a new kind of battlefield

From the chaotic skies over Somalia during the Battle of Mogadishu in 1993, to the covert operation to kill Osama Bin Laden in 2011, Black Hawk helicopters are among the deadliest, most effective tools available to any modern military. After its experiences in the Vietnam War in the 1960s and 70s, the US military knew just how essential it was to have tough, multi-role helicopters available. Not only were these aircraft useful for rapidly transporting combat personnel to and from battlefields, they could even remain on the front line to provide direct support. However, the existing Huey helicopters were out of date.

Two US companies, Boeing Vertol and Sikorsky, went head-to-head with their rival designs for the new combat helicopter, with the latter finally winning the contract with its S-70 prototype. Since the model first took to the skies in 1974, a huge number of variants have gone into production, each with its own specific role to play in a combat zone. For instance, the secretive 'MH-X' version – used during the mission to kill Al-Qaeda's chief – was rumoured to be equipped with stealth technology, making it almost undetectable to radar.

The MH-60 variant seen here was developed from the standard UH-60 Black Hawk for use during special operations. The machine's effective range was greatly increased with the addition of a more efficient fuel tank, the installation of systems for aerial refuelling, and the improvement of the craft's overall survivability. It was during a special operation that these assets would be put to the ultimate test, an incident known as Black Hawk Down.

The Black Hawk is capable of carrying a range of weaponry, and will often house a door gunner for protection in hostile environments

Inside a Black Hawk

The high-powered tech behind the MH-60 military machine

Machine guns
Two electrically powered M134 Miniguns, capable of firing a combined 12,000 rounds per minute, can be mounted on the aircraft.

Optional extras
Black Hawks can be fitted with Hellfire anti-tank missiles and rocket pods, as well as additional fuel tanks for long-haul missions.

"Black Hawk helicopters are among the deadliest and most effective tools available to any modern military"

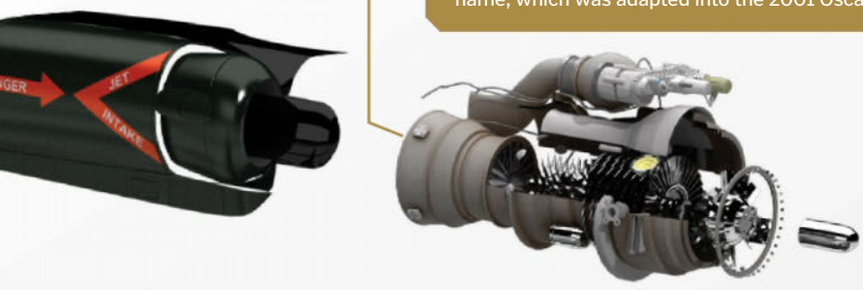
The Battle of Mogadishu

On 3 October 1993, American Rangers flew into Mogadishu, the capital of Somalia, to capture a wanted terrorist leader. They swooped down on the target's base in a convoy of helicopters, with MH-60 Black Hawks hovering overhead to provide support. However, when two of these aircraft came under fire, they crash-landed into the maze of streets and alleyways below. What was supposed to be a smooth operation soon turned into chaos as soldiers battled through the streets to reach the downed aircraft and their stricken crew. The ensuing battle is now most famously known as Black Hawk Down, due to the 1999 book of the same name, which was adapted into the 2001 Oscar-winning film.

A Black Hawk flies over Mogadishu during Operation Restore Hope, a year before the Battle of Mogadishu

Twin engines

Two General Electric engines pack a combined 3,988 shaft horsepower, enabling the aircraft to reach a top speed of 280km/h.



The use of night-vision (infrared) technology enables pilots to safely conduct special operations in total darkness

Safety features

The fuel tank, landing gear and body frame are all reinforced to protect the crew in the event of a crash. Even the pilots' seats are designed to absorb and nullify any critical impact.

Radar

As well as GPS capability, the MH-60 is fitted with multi-mode radar capable of tracking the terrain below, even in poor weather conditions.

Passengers

Up to 18 personnel can be transported in the rear of the aircraft, which has an operational range of over 2,200km.

Night vision

A forward looking infra-red (FLIR) video camera pod captures the surrounding environment and relays it to the pilot, enabling safe flight in total darkness.

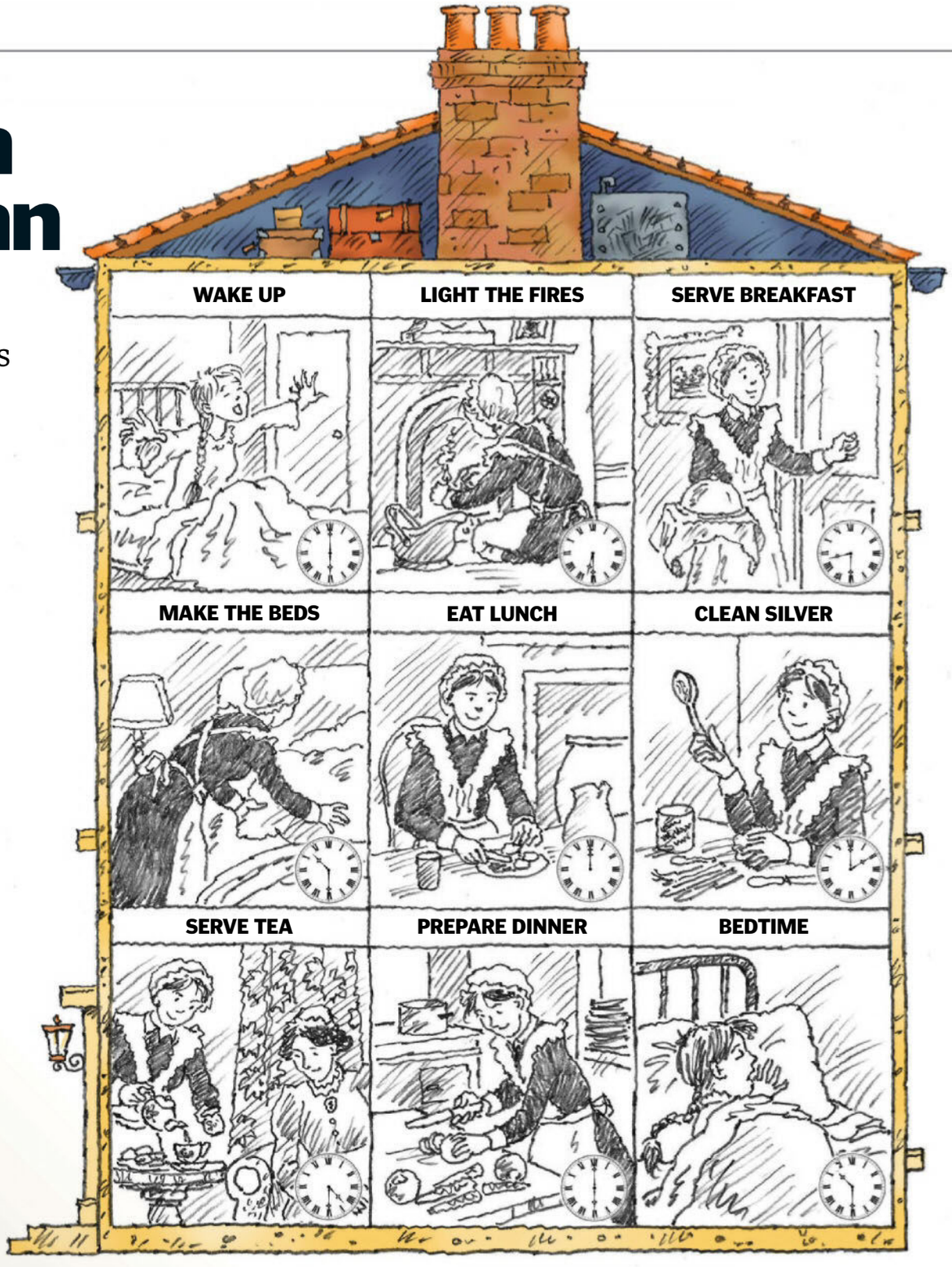
Life of a Victorian maid

Discover the daily toils and troubles of a 19th century housemaid

In the large country homes and townhouses of Victorian Britain, it was a maid's job to be unseen and certainly not heard. That wasn't always easy when there was work to be done in every room of the house, and with gruelling shifts that were often 16 hours long. From the crack of dawn until the last drop of port had been drunk, a housemaid's day was filled with cleaning and clearing, serving and sweeping.

Without modern-day appliances like vacuums and dishwashers to help them, this was no mean feat. Many suffered from ailments like 'prepatellar bursitis', an inflammation of the knee, caused by many hours spent scrubbing floors. Despite this, they considered themselves lucky to have a roof over their head, let alone a job. After all, sore knees were nothing compared to the horrors of the workhouse.

Maids were often recruited as young as eight years old and many came from the country, as they were considered more adaptable and harder working than children from the cities. A housemaid, who was responsible for general jobs around the house, earned about £16 a year – equivalent to a measly £960 ($1,370) today. On the plus side this included board, lodging and clothes, and when you were working seven days a week, there was very little time to spend money anyway. The work varied depending on the size of the household and how many servants there were. Each day had a strict routine, and there wasn't a single minute when there wasn't work to be done.



The daily routine

A Victorian maid's schedule was a never-ending list of chores

06:00 Wake up
Our maid wakes and quickly dresses. Her uniform is a simple black dress, a pinafore and a cap.

06:30 Light the fires
The carpets are swept and the fireplaces cleaned before new fires are lit. The family are then woken.

08:30 Serve breakfast
After eating her porridge, the maid brings out breakfast for the family. This often includes eggs, sausages and kippers.

10:30 Make the beds
After clearing the breakfast table, it's time to clean the family bedrooms, make the beds and scrub the bathrooms.

12:00 Eat lunch
The servants have their main meal at midday. It's usually meat and potatoes followed by a boiled pudding.

14:00 Clean silver
Once the family has eaten a three-course lunch, the table is cleared, the dishes washed, and the silver polished.

16:30 Serve tea
Our maid has barely finished clearing up after lunch when the bell rings for afternoon tea.

18:00 Prepare dinner
The family eats dinner at 20:00, but before then there are vegetables to be chopped and a table to be laid.

22:30 Bedtime
When the dishes are washed, and after a quick supper of bread and cheese, it's finally time for bed. Phew!

Examine the Past

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MEET THE EXPERTS

Who's answering your questions this month?

Luis Villazon

Luis has a degree in zoology from Oxford and another in real-time computing. He builds steampunk gizmos and electronic gadgets, and his articles about science, tech and nature have been published around the world.

Laura Mears

Laura studied biomedical science at King's College London and has a master's from Cambridge. She escaped the lab to pursue a career in science communication and also develops educational video games.

Alexandra Cheung

Having earned degrees from the University of Nottingham and Imperial College London, Alex has worked at many prestigious institutions, including CERN, London's Science Museum and the Institute of Physics.

Sarah Bankes

Sarah has a degree in English and has been a writer and editor for more than a decade. Fascinated by the world in which we live, she enjoys writing about anything from science and technology to history and nature.

Shanna Freeman

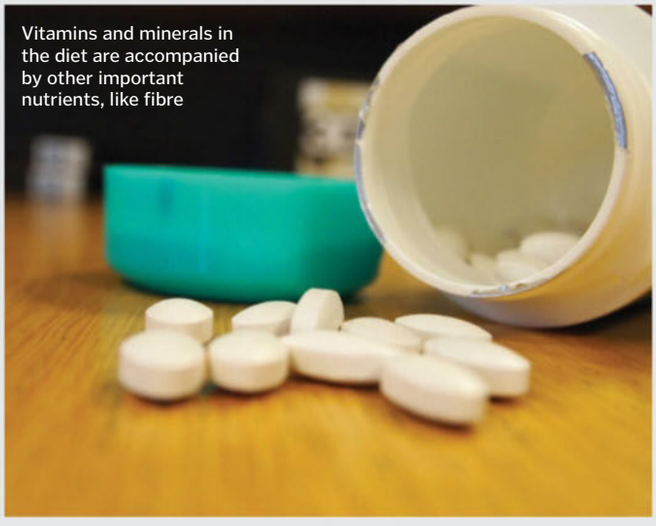
Shanna describes herself as somebody who knows a little bit about a lot of different things. That's what comes of writing about everything from space travel to how cheese is made. She finds her job comes in very handy for quizzes!

Male blue-footed booby birds perform a courtship dance as part of their mating ritual

Do animals flirt?

Mark Rawle

Not exactly. Among humans, flirting is typically a subtle, covert way of getting across the message that you find someone else attractive. It's about picking up on cues and signals, which aren't the same for everyone and can easily be missed or misinterpreted. Animals tend to put out the message loud and clear, either through actions or appearances, when they're looking for a partner. Many male bird species have courtship dances or flamboyant displays of feathers, for example. The rumps of female bonobos (a species of great ape) get puffy and pink when they're fertile and ready to mate. Some scientists think that people are subtler than animals about their sexual attractions because we can have a lot to lose, socially, by being really obvious. **SF**

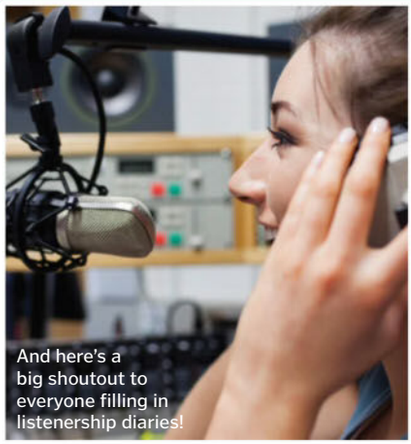


Vitamins and minerals in the diet are accompanied by other important nutrients, like fibre

Do vitamin supplements actually work?

Alistair Bryans

The answer to this question depends on what you mean by 'work'. Vitamins and minerals are vital for the body to function properly, and deficiencies can lead to a whole host of different medical problems. If people are deficient in vitamins or minerals because they aren't getting the right amounts in their diet, supplements can help to bring their bodies back up to normal levels. However, whether they provide additional benefits if you are already getting enough in your diet is still a matter of debate, and in fact, too much of some vitamins can actually be harmful. For most people in the UK, it is possible to get enough vitamins and minerals from diet alone. **LM**



And here's a big shoutout to everyone filling in listenership diaries!

How do radio stations know how many listeners are tuning in?

Hattie Sawyer

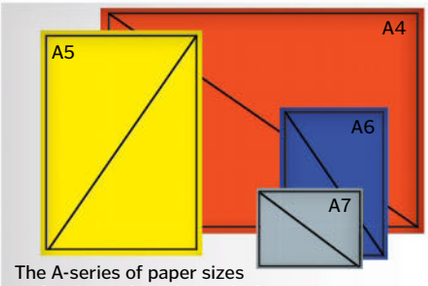
In the UK, this is handled by RAJAR (Radio Joint Audience Research), a non-profit organisation partly owned by the BBC. Thousands of randomly selected households are asked to keep weekly diaries recording all the radio stations they listen to. In each household, one adult and up to two children will keep their own diaries. The data is collected every week, except for the two weeks of Christmas and New Year, and the average quarterly results are published for all national stations. Local stations publish rolling average figures for the last six or 12 months. **LV**

Why does the night sky sometimes look orange?

Guy Hendrix

The orange glow that you see at night close to towns and cities is caused by artificial lighting, and is often described as light pollution. Streetlights, floodlit buildings, sports grounds and uplit billboards all contribute to this form of pollution by shining some of their light upwards. This results in night skies up to 1,000 times brighter than they would be naturally. Under cloud cover, the orange colour is especially pronounced as clouds reflect long-wave, reddish light particularly well. Light pollution can mask the glow from distant stars, as well as interfere with the circadian rhythms of both animals and humans. **AC**

Light pollution is a problem in urban areas across the globe



The A-series of paper sizes makes it much easier to deal with large volumes of paper

Why is paper sized A3, A4 etc?

Toby Curtis

The A-series of paper sizes is based on a German standard originally from 1922, although it was set as part of an official metric standard much later, in 1975. Smaller sizes of paper are exactly half the previous paper size, and each size in the series is exactly the same shape, with a width-to-height ratio of 1:1.41. Metric paper weights are usually measured in grams per square metre (gsm), so the A-series of paper sizes makes mass calculations far easier when handling large volumes of paper. It also doesn't cause any stretching issues when scaling up and scaling down, thanks to using the same ratio. **SB**

What happens to fizzy drinks in space?

Gabrielle Patterson

Without gravity providing an 'up' and a 'down', the bubbles of carbon dioxide in fizzy drinks would remain randomly distributed in the liquid. Here on Earth, gravity creates a density gradient within a glass of carbonated drink. Since the bubbles that form are less dense than the liquid around them, they are pushed toward the top and emerge at the surface of the drink. Under microgravity, these bubbles would remain in the liquid, moving randomly and merging with other bubbles as they collided. The result would be a mass of foam with bubbles of different sizes. Drinking fizzy drinks in space can be hazardous to astronauts because the bubbles cannot separate from the liquid. Once swallowed, gas cannot rise and be 'burped' out, meaning that astronauts would end up with large quantities of carbon dioxide in their digestive systems. **AC**

Fizzy drinks behave very differently on Earth to how they would in space

FASCINATING FACTS

What temperature is the human brain?

Core body temperature hovers around 37 degrees Celsius, but the brain is actually at least 0.2 degrees warmer. Differences larger than this may be a sign of brain damage or inflammation. **LM**

The brain is actually slightly warmer than the rest of the body

BRAIN DUMP

You could fit every *Star Wars* movie, plus the directors' commentaries, on a single Blu-ray disc

What is the real difference between Blu-rays and DVDs?

Max Cookney

The fundamental difference is the wavelength of the laser light used to read them. DVDs use a red laser with a 650nm wavelength, while Blu-rays use a 405nm laser (it's actually more of a violet colour, rather than 'Blu'). Because the wavelength is shorter, the beam can be focused to a much sharper point. This allows the pattern of pits and gaps that represent the digital data to be smaller and the spiral tracks on the disc can be much closer together. The tighter packing means a Blu-ray can hold up to 50GB of data for a dual-layer disc – five times as much as a DVD. The data layer on a Blu-ray is much closer to the surface than on a DVD, so Blu-ray discs need a special hard coating, on top of the normal clear polycarbonate that the disc is made of, to protect them from scratches. **LV**

Moby Dick was based on real-life events, although the whale itself wasn't real

Was there a real Moby Dick?

Tristen Lyons

The whale known as Moby Dick in the novel of the same name was not a real whale. However, the novel was based on real-life events. Born in 1819, American author Herman Melville lived in the period leading up to the American Civil War, when the American whaling fleet reached its all-time peak. Melville himself spent many years at sea as a whaler. The novel incorporates his own experiences, as well as accounts of others at the time, including those of Captain George Pollard. The name was even derived from a real whale called Mocha Dick, which Melville read about in a magazine. **SB**

FASCINATING FACTS

What altitude must satellites reach to stay in orbit?

The lowest possible orbit is around 160km above the Earth's surface. Below this, the atmosphere is dense enough to cause significant friction and therefore drag, slowing down objects and causing their altitude to drop rapidly. Most satellites are at least 300km away. **AC**

The International Space Station orbits Earth at an altitude of 400km

Are foxes more closely related to cats or dogs?

Foxes are part of the Canidae lineage of carnivorans that also includes domestic dogs, coyotes, jackals, dingos and wolves, so they are much more closely related to dogs than they are cats. **SB**

The red fox is one of the most widely distributed canines

How long does it take for alcohol to leave your system?

It can take anywhere from 30 minutes to two hours for a unit of alcohol to leave your system. It depends on the alcohol content of your drink, your gender, weight and lots of other factors. **SF**

It is hard to predict how quickly alcohol will leave your body

Elephants aren't scared of mice specifically, but rather any fast-moving creature

Are elephants actually scared of mice?

Annie Gilchrist

Elephants are not scared of mice, but they can become spooked if one runs past them. The elephant's poor eyesight combined with the speed of a darting mouse has led people to believe they have a specific fear, and the comical sight of a huge animal being scared of a tiny one has become popular. However, any other fast-moving creature would have the same effect. In fact, in an experiment where non-moving mice were shown to elephants, they produced no reaction whatsoever! **SB**

How are clear ice cubes made?

Kendra Kozlowski

Ice made in an icemaker at home is cloudy, but you may have noticed that high-end restaurants and bars often serve crystal-clear ice. Restaurants like this have expensive commercial icemakers that use pure water (free of chemicals or other impurities), cool it at just the right rate to avoid cracking, and keep it bubble-free. Some people have found that it's possible to make clear – or at least, clearer – ice at home by using distilled water or boiling tap water twice and letting it cool a bit before putting it in the ice trays. **SF**

Clear ice is a lot harder to make than the normal, cloudy kind

Why does your nose become blocked one nostril at a time?

Jen Chapple

It might surprise you to know that even when you are healthy you only breathe through one side of your nose at a time. Every two or three hours, the blood vessels in one side of the nose constrict, while those in the other side relax, causing one nostril to swell slightly in comparison to the other and redirect the flow of air. Normally, one nostril is enough to provide the air that you need, and the nasal cycle gives each side a break to avoid it becoming dry and sore from a constant airflow. However, when the nasal passages are inflamed or filled with mucus, there is more resistance, and it suddenly becomes obvious that you are only using one nostril. **LM**

The nostrils have a regular cycle, taking turns every few hours

Some foods may taste less intense when they're heated

Why does hot food taste better than cold?

Tom Shackleton

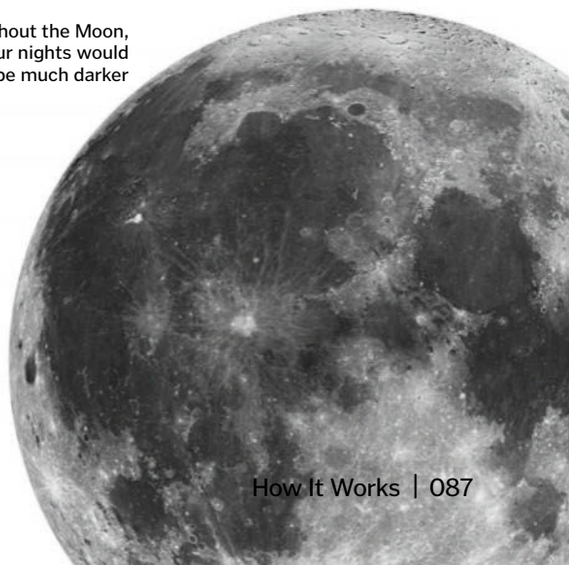
There is a theory that the temperature of foods affects how intense they taste, which means that some taste better warm than others. Ice cream, for example, tastes just right when it's frozen, but too sweet when it's melted, while ham tastes less salty when it's warm. One study has actually found that your perception of taste goes down if your food is hotter than 35 degrees Celsius. **SF**

What would happen if there were no Moon?

Eleanor Senior

If our Moon disappeared, we would immediately notice a difference in our planet's tides, with much greater changes occurring over longer timescales. The Moon's gravitational pull on oceans and sea is responsible for tides and without it, tides would be much weaker, influenced only by the Sun's gravity. Tides also slow down our planet's spin: if the Moon had never existed, our days would be as short as six hours today. The Moon's orbit also has a stabilising effect on Earth. Without our satellite, Earth would be prone to greater wobbling and our planet's axial tilt could fluctuate by several degrees (over millions of years). **AC**

Without the Moon, our nights would be much darker



BRAIN DUMP

Did Earth always have water?

Lizzie MacFarlan

Most of the water that we see on Earth today was brought to our planet by comets and asteroids. When the Solar System formed 4.6 billion years ago, water molecules would undoubtedly have been present in the swirling dust and rocks that accreted to form planets. But with no atmosphere, any water on Earth's surface would have vaporised under the high temperatures and escaped into space. However, over the next 700 million years, our planet was pummelled with comets and asteroids. These contained ice, which became liquid water once it reached our planet's surface. **AC**

Almost all the water in our oceans came from comets and asteroids

FASCINATING FACTS

What do the coloured blocks on food packaging mean?

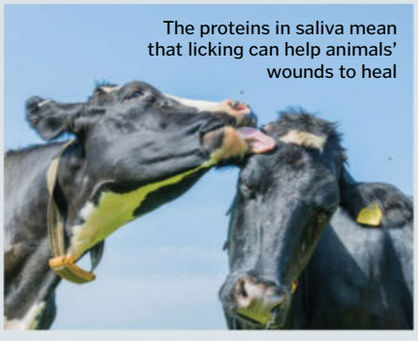
They mean that the packaging manufacturer's printer is working properly! The coloured circles are called process control patches and there is one for each of the ink colours used on that label. **LV**

Process control patches are often hidden behind a fold, or tucked away on an inconspicuous area

Why do animals lick their wounds?

Craig Bourlet

The response by animals to lick a wound is often instinctive. It can help to remove hair and dirt that surrounds the wound – wild animals have few alternatives for cleaning it up. However, there is also a scientific explanation as to why animals lick their wounds. Saliva contains a protein known as tissue factor, which encourages blood clotting to take place. This happens thanks to two special enzymes known as lysozyme and peroxidase, which attack the cell walls of some types of bacteria and consequently help to fight infection. Licking also delivers protease inhibitors, molecules that inhibit the function of proteases, as well as growth factors. Although licking wounds can be beneficial to animals, it's important that they don't get too carried away, because their mouths also contain bad bacteria that can make the wound worse. **SB**



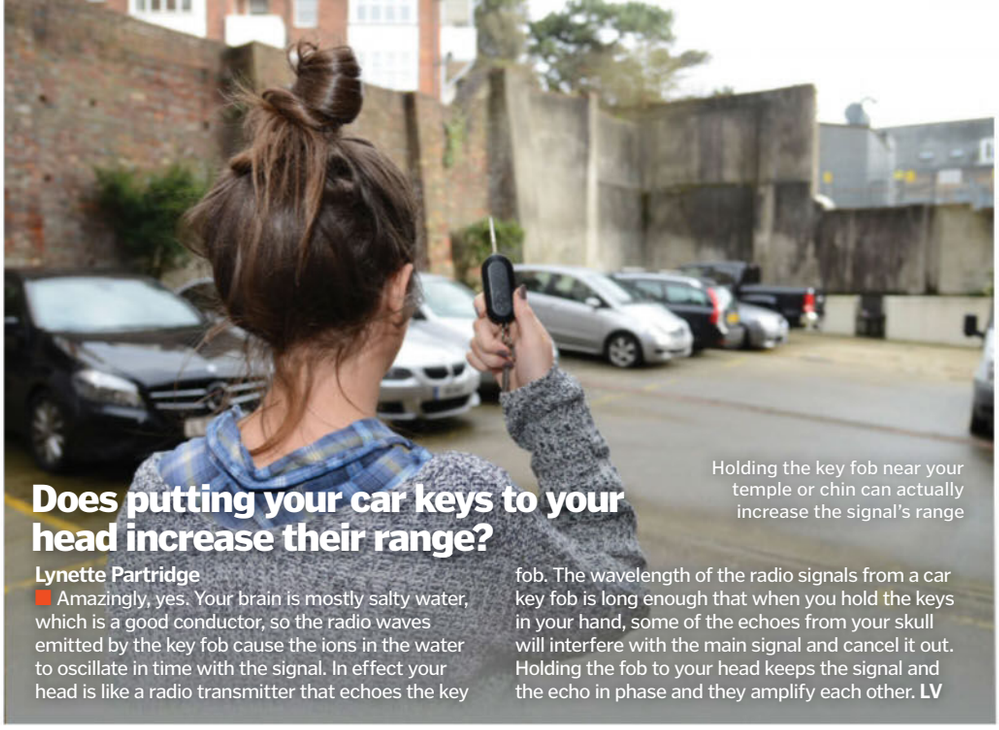
The proteins in saliva mean that licking can help animals' wounds to heal

Male mandrills use red pigmentation as a natural stop sign, to emphasise their dominance

Why are stop signs red?

Rory Salter

Red has been a danger signal for a long time in our evolutionary history. Research using rhesus macaques has found that the monkeys are much less likely to take an apple slice from a human handler if they are wearing bright red clothing. This may be because red is the colour of blood and indicates a flushed, angry face. The roadside stop sign originated in 1915 in the US, but was initially black and white. It wasn't until 1954, when companies could produce long-lasting red reflective material, that the stop sign as we know it today was introduced. **LV**



Holding the key fob near your temple or chin can actually increase the signal's range

Does putting your car keys to your head increase their range?

Lynette Partridge

Amazingly, yes. Your brain is mostly salty water, which is a good conductor, so the radio waves emitted by the key fob cause the ions in the water to oscillate in time with the signal. In effect your head is like a radio transmitter that echoes the key fob. The wavelength of the radio signals from a car key fob is long enough that when you hold the keys in your hand, some of the echoes from your skull will interfere with the main signal and cancel it out. Holding the fob to your head keeps the signal and the echo in phase and they amplify each other. **LV**

Freckles are linked to the same gene as red hair

Why do some people have freckles?

Karen Brotherton

Freckles are patches of brown or red-brown pigment called melanin, laid down by specialised skin cells known as melanocytes. Melanocytes sit in the very bottom layer of the skin, and in most people they are spread out in an even layer. However, in some people, the melanocytes are arranged in clumps. This has been linked to an inherited difference in a gene called MC1R, which normally codes for a protein that tells melanocytes to make the dark brown version of melanin. If this gene is faulty, a red-brown version of the pigment is made instead, resulting in fair or red hair and, often, freckles. **LM**

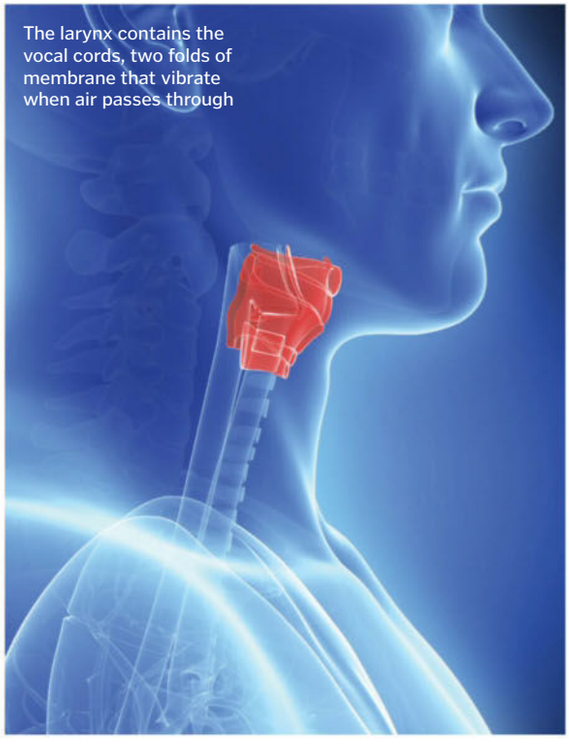
What happens when you lose your voice?

Robyn Mace

Losing your voice is one of the symptoms of laryngitis – inflammation of the larynx, or voice box. It is often caused by viral infection, but can also happen as a result of damage caused by overuse or by noxious substances like cigarette smoke.

The larynx is a hollow organ that connects the back of the nose and mouth (the pharynx) to the windpipe (trachea). It contains two folds of membrane, the vocal cords, which vibrate when air passes through. Normally the vocal cords are flexible, allowing a range of different sounds to be produced, but if they become inflamed, they swell up and stiffen.

To make these stiffened folds vibrate, air must be forced out at a higher pressure than normal, making the voice sound hoarse and strained. In some cases, people cannot generate the pressure required to vibrate their vocal cords at all, and they lose their voice completely. **LM**



The larynx contains the vocal cords, two folds of membrane that vibrate when air passes through

Some people would love to forget their embarrassing memories

Is it possible to forget things on purpose?

Lauretta Zanon

This is a controversial topic among psychologists. All of us have memories that we'd prefer to forget, and a recent study shows that our brains probably make us forget unimportant details to keep things running relatively smoothly. Some psychologists believe that you can force yourself to forget memories by consciously thinking about something else. If true, this could help explain conditions like post-traumatic stress disorder, in which people may have repressed memories. However, not all psychologists even believe that traumatic memories can truly be repressed. So right now the answer is 'possibly' – at least until more research has been carried out. **SF**

New Brain Dump is here!

Don't miss issue 34 of **Brain Dump**, the digital sister magazine to **How It Works**, when it lands on the virtual newsstand on 3 March. In this instalment, you'll discover which animal has the biggest bite, why onions make your eyes water, what household dust is actually made of and why slugs are partial to a boozy beverage! We also answer the question: why is the sea salty? Every edition is packed with stunning images and fun facts to entertain your friends and family with. Download the new issue of **Brain Dump** at the beginning of every month from iTunes or Google Play. If you have a burning question, you can ask at **www.facebook.com/BrainDumpMag** or Twitter – the handle is @BrainDumpMag.

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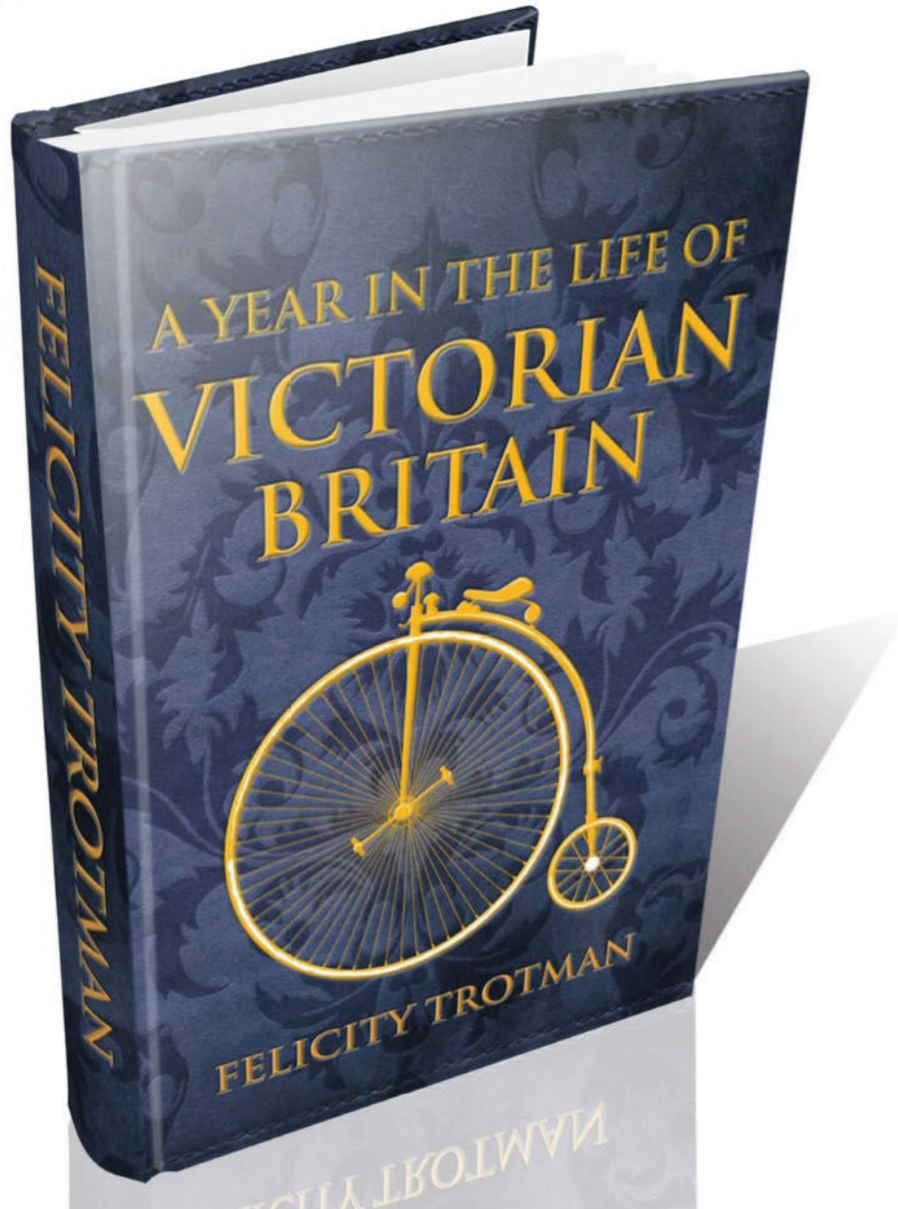
BOOK REVIEWS

The latest releases for curious minds



A Year In The Life Of Victorian Britain

The age of wonder day by day

- Author: **Felicity Trotman**
- Publisher: **Amberley**
- Price: **£20 / $34.95**
- Release date: **Out now**

So often when writing about Victorian Britain, the focus is placed on the poverty, hardship and desperation faced by its denizens. While it's important not to overlook these aspects of the period, the outlook that this book provides is refreshing, focusing on multiple aspects of daily life over the course of a year.

Taking the form of a collection of letters, diary entries, reports, novel extracts and articles, each from a different author, every day of a Victorian year is chronicled in some form. The variety of writers on show is extremely diverse, ranging from notable names of the age, including Charles Dickens, Isambard Kingdom Brunel, Oscar Wilde and Queen Victoria herself, to accounts of tasks such as homemaking and housework from unknowns. Together, it forms a compelling account of life at the time that may not necessarily be the most thorough available, but is undoubtedly illuminating.

Helpfully, most of the entries include a brief biography of the author in question, setting the scene and providing background information where it is needed most. This particularly comes in handy with the extracts from various comedy writings and poems. The Victorian age has gained a reputation as one of stiff upper lips and a lack of humour, which is a myth that this book tries – and ultimately succeeds – to dispel.

Moreover, thanks to the bite-sized entries (the longest isn't much more than a page or two, and the shortest barely a paragraph), it's perfect for light reading. This is a book you can flit back to again and again, either to learn something new or find out what happened on a particular date. It's impossible not to come away from this feeling like you've learned something. It simply sweeps you up with the aid of anecdotes and ditties from an era that's just out of reach.

Those who are used to reading singular accounts of Victorian Britain should definitely pick up this book – concise and regaling, it barely puts a foot wrong. Trotman's work will make a valuable addition to any bookshelf.

★★★★★

YOU MAY ALSO LIKE...

The Year I Was Born: 1956

Author: **Felicity Trotman**
Publisher: **Signpost Books**
Price: **£9.99 / $2.99**
Release date: **Out now**

In a similar, collative style to that used in *A Year In The Life*, Trotman pulls together a group of articles from the year of her own birth, with the same insightful and seamless results.

The Victorians

Author: **AN Wilson**
Publisher: **Arrow Books Ltd**
Price: **£14.99 (approx $21)**
Release date: **Out now**

One of the best books about the age by one of the country's most respected journalists and authors, this is an excellent introduction to the fascinating time period and the profound impact it has had on our society ever since.

A Christmas Carol

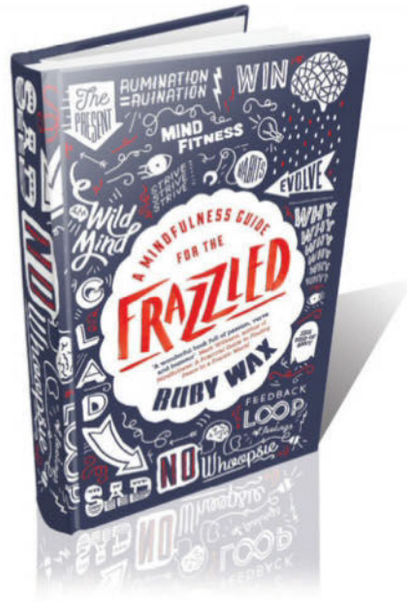
Author: **Charles Dickens**
Publisher: **CreateSpace Independent Publishing Platform**
Price: **£4.99 / $6.99**
Release date: **Out now**

Out of all Dickens' novels, this is one of his more light-hearted and optimistic – while simultaneously providing a serious commentary on Victorian life.

A Mindfulness Guide For The Frazzled

Regain your focus and reduce your stress with science

- Author: **Ruby Wax**
- Publisher: **Penguin Life**
- Price: **£14.99 (approx $20)**
- Release date: **Out now**



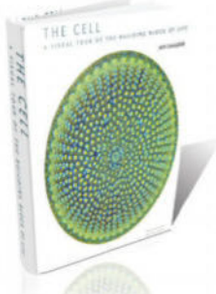
In our busy and stressful lives, we often forget to stop and take note of our thoughts, feelings and the world around us. Actress and comedian Ruby Wax admits that she is guilty of it too, and has written a funny and informative guide on how to be mindful.

Mindfulness is the mental state achieved by focusing on the present, and in her book, Wax includes an easy six-week course on how to achieve it. Using her Oxford Masters degree in Mindfulness-based Cognitive Therapy, she also explains the neuroscience behind it, exploring how being 'frazzled' affects the brain and the health benefits of being mindful, all with a good dose of humour. ★★★★☆

The Cell

Take a closer look at the building blocks of life

- Author: **Jack Challoner**
- Publisher: **Ivy Press**
- Price: **£19.99 / $40**
- Release date: **Out now**



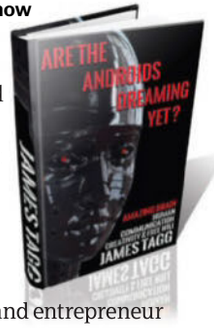
Every single living thing on Earth is made of cells, and yet the natural world is full of such a variety of species and materials. In this beautiful illustrated guide, Jack Challoner manages to explain exactly how these minuscule powerhouses have created such diversity of life in a way everyone can understand.

The balance of short passages of text and useful diagrams and infographics serve as a perfect introduction to the topic, providing a comprehensive guide to life's building blocks. From the history of the cell to current scientific research, there is plenty to sink your teeth into, and the book is also peppered with stunning microscopy images, revealing the hidden beauty inside ourselves, and in the creatures around us. ★★★★★

Are The Androids Dreaming Yet?

Why humans will never be truly outsmarted by computers

- Author: **James Tagg**
- Publisher: **Hurst Farm Books**
- Price: **£14.99 / $19.99**
- Release date: **Out now**



With computers becoming more and more advanced, many believe that it is only a matter of time before we lose the title of 'most intelligent being'. However, inventor and entrepreneur James Tagg argues that we will always be more powerful than any machine, and that communication, creativity and free will make our brains truly unique. Although disjointed in places, Tagg's book examines some important milestones in information science and includes puzzles to test the reader's own intelligence. It's a challenging read that may leave you with more questions than you started with. ★★☆☆☆

Electronic Dreams

How computers invaded the home in 1980s Britain

- Author: **Tom Lean**
- Publisher: **Bloomsbury**
- Price: **£16.99 / $27**
- Release date: **Out now / 29 March US**

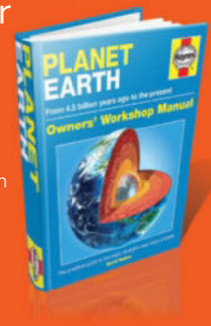
If you're old enough to remember the ZX Spectrum or the BBC Micro, then the pages of Electronic Dreams are sure to evoke feelings of nostalgia. However, even if you're too young to be reminded of the days of single-colour screens and pixilated graphics, you will still find something to love in Tom Lean's fascinating story of the history of home computing. The book explores both the successes and failures of the computer industry, focusing on the people who made them happen. Although likely to only appeal to true computer geeks, Lean still manages to convey the wonder of the technology that changed the world.

★★★☆☆

Planet Earth Owners' Workshop Manual

The ultimate guide to our home in the universe

- Author: **David Baker**
- Publisher: **Haynes**
- Price: **£22.99 / $36.95**
- Release date: **Out now**



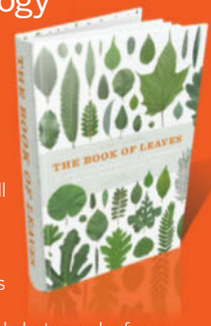
Planet Earth has been around for 4.5 billion years and a lot has changed in that time. This practical guide documents its incredible history, from the planet's formation to the evolution of life on its surface and pretty much everything in between. Broken down into sections, the book includes a wealth of information about Earth's geology, oceans, inhabitants and its place in the Solar System. Explanations are accompanied by fascinating images and diagrams, although some of these are rather complex. Concluding with a look to Earth's future, this manual is a great introduction into how our little blue planet works.

★★★★☆

The Book Of Leaves

Admire the amazing biology of the world's foliage

- Author: **Allen J Coombes**
- Publisher: **Ivy Press**
- Price: **£29.99 (approx $45)**
- Release date: **Out now**



From the trees in your back garden, to the forest giants in the wilderness, leaves of all shapes and sizes can be found adorning branches across the world, but have you ever stopped to take a closer look? This mammoth guide dedicates its many pages to the humble leaf, documenting 600 different varieties with full-colour, life-sized photographs for you to study in detail. Each one is accompanied by information about its distribution, habitat and more, serving as the ultimate reference guide for identifying unfamiliar foliage. The introduction also explains leaf shapes, sizes and anatomy, exploring how they provide trees with the energy they need to grow.

★★★★☆

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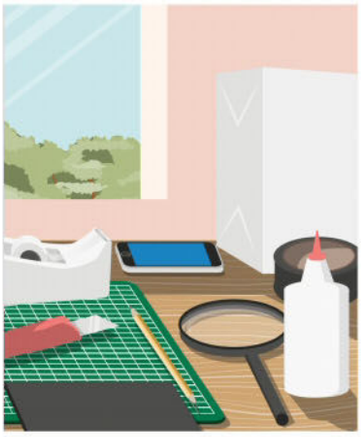
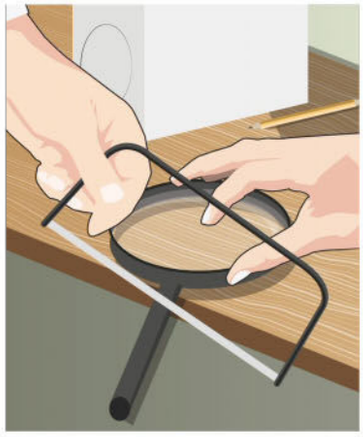
Build a projector

Make your movies massive with this smartphone projector



1 Get your materials

You'll need a few things for this build. A magnifying glass will form the main part of your projector, so find one with a large lens. You'll also need a shoebox to keep the whole thing together, and some glue to make the box secure. A sheet of soft foam can be made into a great stand for your phone, too, so grab some of that before you begin. Your smartphone will slot in when you're ready to start the film!

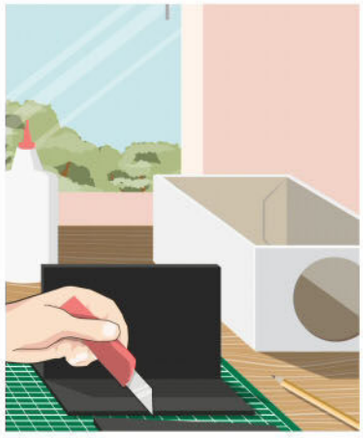


2 Prepare your lens

First, take your magnifying glass and remove the handle from it so you are left with a round lens. You may have a magnifying glass that unscrews, but if you don't, you can use a hacksaw to remove the handle. Then place the lens on one of the narrow sides of your shoebox and draw around it – you'll be cutting out this area in Step 3, so that the lens can project light onto the wall in front of it and create your home cinema.

3 Secure the box

Next, make sure your shoebox is really secure; if the box moves it will affect the focus and orientation of the image on your wall. Put glue under the flaps, spreading it evenly. Then stick the flaps down and leave them for at least ten minutes so the whole box is secure. When it's dry, cut out the hole you drew earlier and stick your lens inside. Be careful not to get glue on the glass of the lens and leave it to dry.



4 Make a stand

Take your soft foam and measure a piece that will fit perfectly inside your shoebox standing vertically. This will be the back of your phone stand. Cut another piece of foam to form the base, then use a hot glue gun to secure the two pieces together. Make sure the angle between the two pieces is exactly 90 degrees – otherwise your phone will be tilted and the projected image may be affected.

DON'T DO IT ALONE
IF YOU'RE UNDER 18, MAKE SURE YOU HAVE AN ADULT WITH YOU

5 Mount, focus and enjoy!

Finally, attach a smartphone case to the soft foam with some double-sided tape and clip your phone into the case. Now the important part – the projected image will be upside down. This means that you'll need to open your movie so that the top of the screen is at the base of the stand, and then lock your phone's orientation. Turn the brightness to full, and move the phone closer or further away from the lens to focus the image. Then grab the popcorn, sit back and enjoy!

In summary...

You have to flip the screen of your phone so it is upside down because the convex lens refracts the light, much like the lens of the human eye. The phone's brightness needs to be high because the light needs to travel much further than normal to appear bright on the wall.

NEXT ISSUE
- BUILD A BALLOON-POWERED ROCKET CAR
- MAKE QUICKSAND

Make a fog machine

Create spooky fog with just a few simple ingredients and a pinch of science!

Illustrations by Edward Crooks

1 Mix your potion

The first thing you need to do is create a liquid mixture that will later turn into fog. You'll need two things for this – distilled water and a liquid called glycerin. This chemical is normally used to make soap as, when mixed in the right way, it is a good moisturiser. Mix one part glycerin with three parts distilled water. When this solution is heated to boiling point, it creates a dense vapour, and when this hits room-temperature air, it turns cloudy.

2 Create a cone

Take a small aluminium pie case and a two-litre drinks bottle. Cut the top off the bottle to create a basic cone shape. This shape should fit perfectly over the small pie tin – attach it with masking tape to ensure it stays fixed on. Next, get an empty soup can and poke several holes in it. We'll be placing a candle in this shortly to heat the glycerin solution, and the candle needs a constant air supply to keep the flame burning.

3 Get foggy!

You should only need a teaspoon of your glycerin solution to fill a normal-sized room with fog. Spoon the mixture into your fog machine through the top of the bottle-cone. Light a candle (preferably one with multiple wicks) and put it inside the soup tin. Place the pie case on top and when the glycerin solution heats up, the fog should start to pour out of the top of the cone. For more fog, simply use a teaspoon to add more of the solution.

In summary...

The science here is all in the mixture. The combination of glycerin and water creates a lower boiling point that can be achieved with the heat from a candle. As the mixture boils, it gives off hot vapour that reacts with the cooler air. This creates an amazing fog-like effect that can normally only be achieved with expensive fog machines!

INBOX
Speak your mind...

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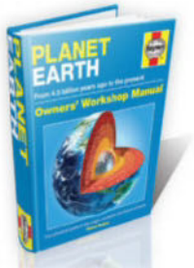
WIN!
We enjoy reading your letters every month, so keep us entertained by sending in your questions and views on what you like or don't like about the mag. You may even bag an awesome prize for your efforts!

AMAZING PRIZE FOR NEXT ISSUE'S LETTER OF THE MONTH!



THE ULTIMATE GUIDE TO PLANET EARTH

Delve into the 4.5-billion-year history of our home planet with this fascinating guide. With amazing images and useful diagrams, learn about Earth's geology, inhabitants and much more.

Letter of the Month

Regrowing lost limbs

Dear **HIW,**
How do starfish grow back their limbs? I've always wanted to know! I hope you get the chance to answer my question.
Many thanks,
Will Haynes, aged 11

To regrow a limb, the starfish must first enter a repair phase to heal the open wound. Once it is healed, a signal is sent to its stem cells – immature cells that can become any type of cell in the body – to initiate new cellular growth. Growing a new limb can be a long process, taking months or even years, depending on the severity of the injury.

Once the limb enters the final growth phase the cells start to multiply rapidly, completing the formation of the new limb. Some species demonstrate autotomy, or self-amputation, in which a limb will be shed and regrown. The shed limb itself is also capable of growing into a whole new individual as a form of asexual reproduction.

Incidentally, scientists are keen for the name 'starfish' to be replaced by 'sea star', as these animals are not actually fish at all. They are echinoderms, belonging to the same family as sea urchins, which can regenerate missing limbs, arms, spines and even intestines in the case of sea cucumbers!


Starfish have been known to deliberately remove a limb to escape predators

Our canine companions

Dear **HIW,**
Can dogs recognise their owners' faces?
Thanks,
Ben Shea

Until recently, the ability to recognise facial features was thought to be possible only for humans and some primates, but it turns out that our canine companions have also developed this skill. A 2010 study by the University of Padua in Italy found that dogs could pick their owners out of a crowd, solely by recognising their faces. However, when the owners wore masks, the dogs struggled to tell people apart and paid equal amounts of attention to everyone. Scientists believe this ability evolved as a survival strategy – dogs learnt to identify friendly humans who would provide them with food or warm places to sleep.

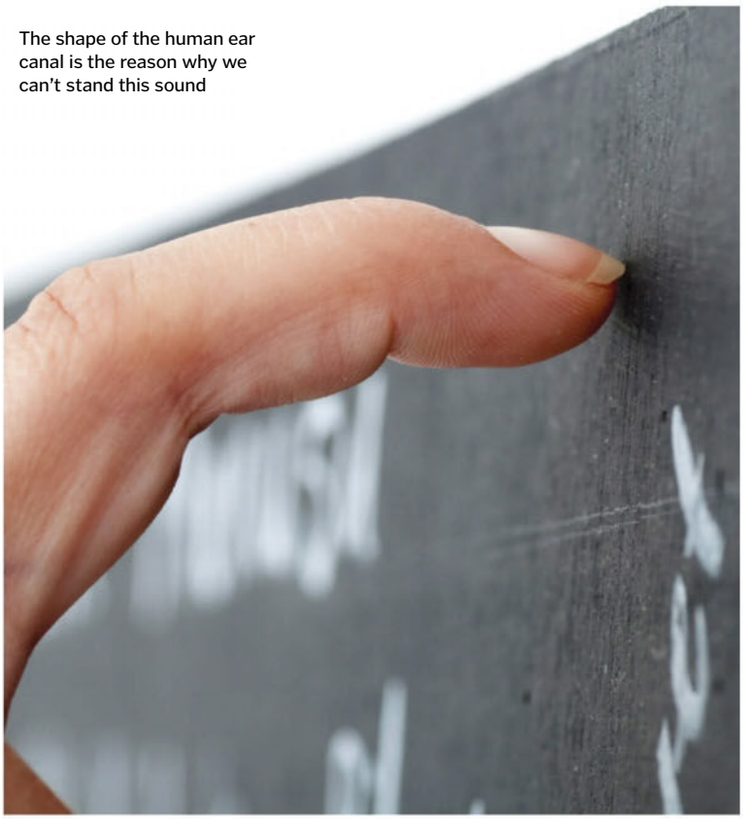

Their sense of smell may be particularly good, but dogs can also recognise faces

Predictive texting

Dear **HIW,**
I enjoy reading your magazine each month, and have got quite the collection! I was just wondering, how does predictive texting work?
Thanks,
Oliver Tucker, aged 13

Predictive texting uses a number of techniques to guess the word or phrase you are typing, to make sending a message as quick and efficient as possible. It accesses a standard dictionary to see the words available from the first letters typed, but also checks the most common phrases the user employs. Many smartphones have software that will build a custom dictionary to provide the best suggestions; it even records the contacts you use slang with so that it can offer these words too.


Modern text message software learns your writing style as you type, helping it to offer the best suggestions



The shape of the human ear canal is the reason why we can't stand this sound

Why we hate nails on a chalkboard

Dear **HIW,**
I am a subscriber and love your magazine! Can you tell me why the sound of nails on a chalkboard is so repulsive to humans?
Thanks again for the wonderful magazine!
Isaac Blyton

Thanks, Isaac! The shape of our inner ear is the reason why we can't stand this noise. Our ears are designed to focus in on human speech, amplifying this specific frequency (2,000-4,000 Hertz) so that we can hear each other. The 'nails on a chalkboard' sound also lies within this frequency, making it very similar to human speech in terms of acoustics. Our ears amplify it as if it was human speech, and we hear it as an unpleasant, piercing sound.

"Our ears are designed to focus in on human speech"

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@chriswgraphics
@HowItWorksmag had a flick through last night, very impressed! Loved the BB-8 and the Nerf gun breakdowns!

@Neilourkid
@HowItWorksmag keep it coming, I love the great 'man facts'!

@UsinDagenham
@HowItWorksmag Our son who is 5 has been asking how we came to be here. The story of humans was perfect for us, and him!

@neiltyson
True science literacy is less about what you know, and more about how your brain is wired for processing information.

@ProfBrianCox
Most surprising thing I discovered in 2015 was that there are actually people alive today who think the Earth is flat! Genuinely baffled!

@WorldClassFacts
5,500 undetonated bombs from WWII are discovered in Germany every year.

@ScienceQuotes2
Wisdom alone is the science of other sciences – Plato.

@AboutHistoryMag
@HowItWorksmag has an ace video on earthquakes. We've always disliked quakes after one destroyed the Colossus of Rhodes.

HOW IT WORKS

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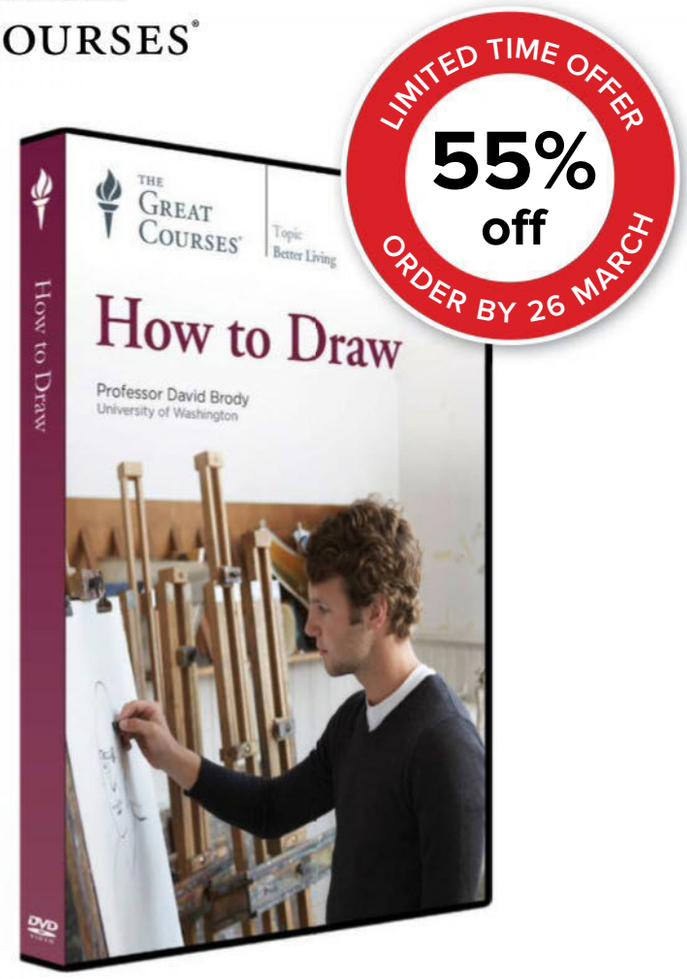

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